Lessons drawn from recent NPP operating experience

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Countries need timely feedback from international nuclear power plant (NPP) operating experience in order to manage the safety of their installations effectively. One way to obtain this type of information is through the annual technical notes about lessons drawn from recent nuclear power plant operating experience prepared by the NEA Working Group on Operating Experience (WGOE). This article is based on the technical note for events experienced in 2003-4[1] (the third in the series[2]).

The WGOE technical notes are based on the issues reported in the joint NEA/IAEA Incident Reporting System (IRS) and, in some cases, the NEA joint safety projects dealing with operating experience data collection and analysis. The safety issues identified in the technical notes are generic in nature and, consequently, useful to decision makers. However, it is also suggested that national regulatory bodies, technical support organisations and nuclear operators put them in national context to see if they are relevant to the safety of the nuclear power plants (NPPs) in their countries.

WGOE

The NEA Working Group on Operating Experience (WGOE) has an important task to refine and report messages from international nuclear power plant operating experience to NEA member countries. This is done via reporting to the NEA Committee on the Safety of Nuclear Installations (CSNI) and the NEA Committee on Nuclear Regulatory Activities (CNRA). Apart from technical notes, the WGOE issues technical reports about selected topics dealing with the analysis of nuclear operating experience, including risk insights where relevant. The group also seeks to advance practices to collect and analyse operating experience in member countries.

Recent safety issues emerging from the Incident Reporting System

Recent events of safety significance reported to the IRS include erosion-corrosion of piping, electrical disturbances, and foreign material intrusion into the primary coolant system. All three of these areas illustrate the continuing need to institute an appropriate and timely corrective action programme both by the utilities and the regulators in order to avoid recurrence.

Electrical disturbances

Several electrical events, both plant-centered and in the off-site grid, have been reported in recent international operating experience. The previous technical note [NEA/CSNI/R(2004)4] reported the August 2003 massive grid disturbance in the United States, which propagated into parts of Canada, and more information has recently been presented. For example, the Pickering station, which consists of eight units, experienced a total loss of off-site power and natural circulation secured the plant cooling for a number of hours. The event revealed deficiencies in a number of safety systems, including emergency service water, firewater, standby diesel generators, and the licensing basis for these and other systems. Corrective actions, including changes in plant design and operation, are currently being taken.

Furthermore, in June 2004 there was a loss of off-site power at the Palo Verde NPP in the United States involving a complete loss of 5 500 MWe

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IRS

The Incident Reporting System (IRS) is the only international reporting system for regulators and governmental organisations which provides an assessment of safety-significant nuclear power plant events, as well as detailed information on analyses of the root causes and lessons learnt from the safety perspective. The IRS is operated by a joint IAEA and NEA secretariat. A guideline for IRS reporting has been in use since June 1998. The system, based on quarterly CD distribution, is now in use in 31 countries. In 2005, it is planned to make trial use of the web-based IRS. Periodic reports on *Nuclear Power Plant Operating Experience* (the "Blue Book") have been published for the periods 1996-1999 and 1999-2002. The next Blue Book for 2002-2005 is planned for spring 2006, in conjunction with the International Conference on Future Uses of Operating Experience scheduled to take place in Germany.

of generating capacity on the grid, including more than 3 700 MWe from the three units at Palo Verde. The cause was traced to a single failure of protective circuitry at an off-site substation. In general, the station responded according to design, although one emergency diesel generator failed to start. It was observed that the transmission company operators had not analysed a situation involving the simultaneous loss of all three units. The event was considered risk-significant and the corrective actions included improvements in the off-site grid components.

These loss of off-site power events had common messages: 1) the operating utilities may have inadequately analysed grid disturbances; 2) there is a need to review operating procedures, communication plans, equipment and the licensing basis for a widespread and long loss of off-site power event, and 3) there may be frailties in the interconnected grids when large concurrent trips of generating capabilities occur.

Foreign material intrusion into the primary system

There have recently been two significant events involving foreign material intrusion. At the Tihange plant in Belgium, a severely damaged spiral-wound metallic gasket was found in a safety injection system check valve, and a fuel failure was observed some months later. The fuel anti-debris devices were unable to catch some portions of the gasket, and the mechanical damage of the fuel cladding was likely caused by pieces of the gasket that went through them.

New and severely damaged gaskets at the Tihange plant.

AVN, Belgium

Another foreign material intrusion event was experienced at the Fessenheim facility in France. A human action on a valve alignment in the chemical and volume control system (CVCS), combined with a design modification, resulted in intrusion of demineralised resins into the primary coolant system. This led to the contamination and exposure of workers, obstruction of the sampling system, and a six-month outage of the facility for cleanup and repair. The nuclear safety consequences included inoperability of a number of control rods, blockage of injection to reactor coolant pump seals, and increased potential for failure of high-pressure injection pumps due to bearing failure.

Although foreign material intrusion is a recurring concern, these two events were particularly significant. The first one led to a fuel failure and the second one to safety system impairments and a long outage.

Erosion-corrosion of piping

As regards piping, a significant event occurred at the Mihama plant in Japan that involved the failure of a condensate water pipe in the turbine hall. The event resulted in severe injuries to plant personnel, including five fatalities. Some of the main features of the event are:

- The ruptured portion of the piping should have been inspected according to plant guidelines. However, it had not been inspected since the plant start-up in 1976.
- An unauthorised residual life evaluation rule was applied by the plant operating organisation.

- The quality management system of the operating organisation was not sufficient to check the contracted work.
- The secondary piping inspection had been within the scope of the utility's self-imposed inspections.

A number of precursor events have taken place at similar plants, for example in Japan and in the United States (e.g. at Surry in 1986), and many of them may be found in the IRS database. As a corrective action, improvements in inspection practices of both the operator and the regulator are being considered and/or already applied. For instance, since 1 October 2003 this previously self-imposed inspection is now legally required, and the Japanese regulatory agency NISA (Nuclear and Industrial Safety Agency) reviews secondary wall thickness inspection by the utilities. In addition, the Japanese Society of Mechanical Engineers is preparing a piping thickness management standard, and NISA has recently issued guidelines for the inspection and management of pipe and wall thinning.

Recent safety issues emerging from other WGOE work

Other work carried out by the WGOE has highlighted additional safety issues including recurring events, events involving the use of and performance of contractors, and the origins of common-cause failures (CCFs).

Recurring events

The WGOE has continued to study recurring events (it previously issued two reports on the topic). The latest theme concerns corrective actions against PWR loss of decay heat removal in reduced inventory conditions during outages. More than 50 such events have occurred over the past 25 years. Several types of regulatory corrective action approaches have been used, ranging from information notices, advisories and suggestions, to formal and binding decisions by the regulatory authorities. In 1988, the US NRC issued a generic letter with non-binding suggestions on means for reducing the number of occurrences. A notable effect was observed, but events continue to occur, even in 2004. By contrast, for instance, France and Korea issued binding requirements that seem to have stopped the recurrence there. In France, an automatic makeup function was provided; a detailed work schedule and necessary conditions were required prior to mid-loop entry; and a vortex detection device was installed. In Korea, there were requirements for better training of staff, better level instruments, revision of residual heat removal pump procedures, review of critical level calculations and revised technical specifications.

The WGOE is currently investigating whether a similar study on the risk-significant issue of loss of heat sink or loss of service water to safety-related equipment should be initiated.

Events involving contractors

The theme chosen for the WGOE in-depth discussion at its annual meeting in 2004 was the influence of contractor (and subcontractor) work on the evolution of events. There is an increasing use of contractors and subcontractors in the nuclear industry, although outsourcing is not new. Concerns about the use of contractors have increased lately due to the fact that both the licensee and the contractor organisations may experience loss of competence via outsourcing. Small utilities and regulatory bodies dealing with large and sometimes multinational contractor organisations seem to be most vulnerable to this.

Member countries gave several presentations about events involving contracted work, including a brief interruption in decay heat removal due to maintenance during an outage, a plant start-up before some scheduled contracted work could be completed, and manufacturing deficiencies in the component cooling water system heat exchangers.

Ideas on how to avoid problems with contracted work and to improve the situation were presented. There was agreement that the licensees must be able to exercise contractor supervision in all circumstances. However, some events indicate a growing problem of detecting substandard performance. In addition, the licensees need to qualify the contractors, but the procedures for this may not be adequate or even exist in the light of recent experience. Furthermore, matters such as training on nuclear-specific requirements must be addressed by the licensee.

Contracting and subcontracting may, if not handled adequately, lead to losing a long-term safety focus. Core competencies must always be kept in-house in order to remain an intelligent customer. This includes, independently of the domain, the ability to qualify contractors, oversight of training of contracted personnel, supervision and approval of contracted work, and most importantly, continuing involvement in the maintenance of safety-focused thinking.

ICDE

The International Common-cause Data Exchange (ICDE) project was initiated in August 1994. The countries participating in the third agreement phase of ICDE are: Canada (CNSC), Finland (STUK), France (IRSN), Germany (GRS), Japan (NUPEC/JNES), Republic of Korea (KAERI), Spain (CSN), Sweden (SKI), Switzerland (HSK), United Kingdom (NII) and the United States (NRC). The objective of the ICDE project is to draw qualitative and quantitative insights from international operating experience data to help avoid common-cause failures or to mitigate their consequences. The ICDE data include both those events reported to regulatory bodies and those based on additional analysis of proprietary nuclear power plant databases. The main findings of the project are reported publicly.

Common-cause failures of batteries

The International Common-cause Data Exchange (ICDE) project has exchanged information on common-cause failures (CCFs) for more than ten years. The project's most recent report, issued in late 2003, was about batteries.[3]

Deficiencies in design were involved in about half of all the events. Of those, more than 90% occurred during battery manufacture, e.g. inadequate selection of component materials for the plates, in the electrolyte, in separators, in cells, or in terminal connections, and less than 10% occurred during the plant specification or modification process, e.g. calculation errors in the capacity definition. Deficiencies in maintenance and testing were involved in less than half of the events. Of these, approximately half were due to physical failures in the battery subcomponents, nearly 30% were due to electrical failures, some 20% due to direct human actions, and one event was due to premature ageing caused by lack of maintenance. The data suggests that the majority of maintenance and testing events could be prevented with adequate practices and surveillance of the circuit continuity.

Generally, the main areas for improvement to prevent common-cause failures at NPPs are, according to the project findings: 1) scrutinizing existing operation, maintenance and testing procedures for deficiencies creating the potential for CCF of redundant systems, 2) ensuring comprehensive work control, 3) comprehensively prescribing the testing steps required in the requalification of components or systems after maintenance, repair or backfitting work, and 4) intensifying training, introducing ergonomically better designs and introducing more key locks. These findings apply to all component types which have been analysed in the ICDE project.

Concluding remarks

Almost all of the significant events reported recently in international meetings have occurred earlier in one form or another. Similarly, most of the topics highlighted in the 2001-2 and 2002-3 technical notes are still valid. Counteractions are in many cases well-known, but information does not always seem to reach end-users and/or corrective action programmes are not always rigorously implemented. More needs to be done internationally to share experience on safety issues and their solutions, and to make sure that the information reaches the end-users at the NPPs.

The main findings that operation and maintenance dominate as causes for common-cause failures, and a number of recent events dealing with the increased role of contractors and subcontractors, show that the utilities and regulators may need to enhance oversight of the organisational arrangements, competence and safety culture of the licensees to ensure the safe operation and maintenance of NPPs.

Finally, an operating experience reporting and analysis programme is a prerequisite to successful safety management and is stipulated in the Convention on Nuclear Safety. In addition to this, many problem areas also require a review of operating experience on lower levels than plant events and combining this review with other analyses – such as PSA, organisational and task analyses, materials analyses and thermal hydraulic calculations – to find permanent solutions. Such a cross-disciplinary approach challenges the nuclear safety community to progress to the new era of safety management. ■

Notes

1. "Lessons Drawn From Recent Nuclear Power Plant Operating Experience", NEA/CSNI/R(2005)4.
2. The first two WGOE technical notes are referenced as NEA/CSNI/R(2002)24 and NEA/CSNI/R(2004)4.
3. "ICDE Project Report: Collection and Analysis of Common-cause Failures of Batteries", NEA/CSNI/R(2003)19.