P. Pyy, D.F. Ross*

Recurring events: a nuclear safety concern

Nuclear power plant operating experience consists of many types of events with different impacts on safety. Generally, common-cause failures (CCFs) represent the highest risk, since CCFs could make several redundant trains of a safety system inoperable at the same time. Apart from CCFs, the complete or partial repetition of nuclear incidents has also gained attention recently. This phenomenon is called recurrence.

One early example of a recurring event is the Three Mile Island (TMI) accident of March 1979. A similar event had occurred about 18 months before, although with no consequences as the reactor was at low (9%) power. The lessons of the earlier event had not been appreciated. Over the past years, many recurring events have been observed, though fortunately of lesser severity than that of TMI.

What is a recurring event and how is it analysed?

The Working Group on Operating Experience (WGOE) of the NEA Committee on the Safety of Nuclear Installations (CSNI) has produced two reports on recurring events. It also sponsored a workshop on this topic in collaboration with the International Atomic Energy Agency (IAEA) and the World Association of Nuclear Operators (WANO) in March 2002.

As one result of that work, the following definition has been developed for recurring events:

"An event with actual or potential safety significance that is the same or is very similar to important aspects of a previous nuclear industry event(s), and has the same or similar cause(s) as the previous event(s). Additionally, for an event to be considered as recurring, there should exist prior operating experience with corrective actions either:

i) identified but not specified, or

ii) not adequately specified, or

iii) not implemented, or not implemented in a timely manner by the responsible organisation."

Analysis and evaluation of nuclear operational events have been among the most vital nuclear safety activities for decades. The need to perform this analysis was recently emphasized in the Nuclear Safety Convention (Article 19). Consequently, there are many databases of operating experience for various levels, from plant level disturbances to component data. For instance, the NEA and the IAEA jointly operate the Incident Reporting System (IRS). Industry has, through the World Association of Nuclear Operators (WANO), established another system. Each regulatory body has its own national operating experience system for plant event collection and analysis. In addition, individual utilities, owners groups by reactor type, and reactor vendors have systems tailored to individual needs.

In reflection of the multitude of systems to collect and analyse operating experience, there seems to be no single method for searching for recurring events in a systematic fashion. Hence, the identification of recurring events has been

* Dr. Pekka Pyy (pekka.pyy@oecd.org) is a member of the NEA Nuclear Safety Division. Dr. Denwood F. Ross (DFR@nrc.gov) is a consultant to the NEA.

done primarily on a case-by-case basis. This observation has warranted WGOE work on improving techniques and methods for the review of operating events.

Examples of recurring events

In the 1990s, in response to a repetition of similar types of events or/and causal factors, NEA member countries decided that a more systematic study of recurrence was required. The first WGOE report[1] identified four examples of recurring events: loss of residual heat removal in PWR mid-loop conditions during outages, BWR instability, service water system clogging and valve pressure locking.

A recurring event of particular interest for pressurised water reactors is the loss of residual heat removal (RHR) cooling while at mid-loop conditions. Some aspects of this scenario are: the primary system is generally open to the containment atmosphere; the main containment may be open; decay heat is being removed by the RHR system; and the steam generators may not be available for RHR. More than 20 occurrences of loss of RHR at mid-loop conditions were observed during the time period 1980-1996, i.e. more than one per year. The events were widely publicised and regulatory bodies made numerous communications. Even so, such events continued to occur.

Another recurring event concerns instability in boiling water reactors. A usual design criterion for BWRs is that either the reactor remains stable by design, or else instabilities are detected and corrected. However, over the period 1982-1995 about ten instances of BWR instability were detected. In some cases, the oscillations were between 40 and 90% neutron power, and the utilities were somewhat surprised when inadvertent instability was experienced.

A third example of recurring events is the reduction or interruption of service water due to buildup of marine life, including clams, barnacles, shrimps and molluscs. Seven such cases were noted over the period 1980-1997. Service water plays an important role in transporting energy from key systems to the ultimate heat sink.

Assessment of recurring events

The results of the first phase of WGOE work showed that there were many reasons to continue this and to involve utilities too. One follow-up action to the first recurring event report was the organisation of an international workshop on this subject, held in March 2002 in co-operation with WANO. This workshop[2] significantly contributed to international knowledge about the causes of recurrence and corrective actions. It also produced invaluable material for the second report[3] on recurring events issued in 2003.

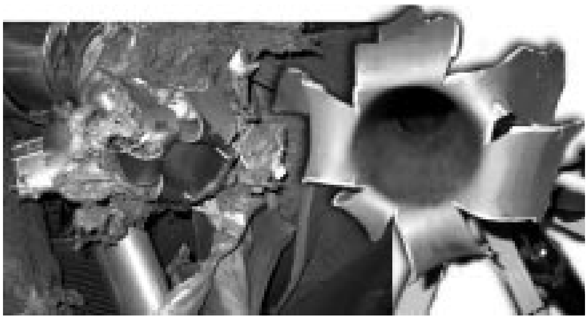
The recurring events identified in the second report are listed in the box. Three recurring events identified in this second report were also identified in the first report. This lends substance to some of the causes of recurring events, notably poor feedback on operating experience.

Examples of recurring events

1. Loss of residual heat removal (RHR) at mid-loop
2. BWR instability
3. PWR vessel head corrosion
4. Hydrogen detonation in BWR piping
5. Steam generator tube rupture
6. Multiple valve failures in the emergency core cooling system (ECCS)
7. Service water system biofouling
8. System level failures due to human factors
9. Strainer clogging

One example of a recurring event newly identified in the second report is PWR corrosion. Two safety-significant recurring events involving degradation of a PWR upper vessel head were reported. Boric acid leaked through cracks in the control rod drive module and attacked the head material. In places, the only remaining control of the primary pressure boundary was the stainless steel cladding. Prior occurrences of corrosion of the upper head or other carbon steel pressure-retaining parts due to boric acid had been reported in a number of member countries, some as far back as 20 years.

As a second example, hydrogen detonations within BWR piping have been reported by several stations. In some cases the immediate consequence was loss of emergency core cooling system (ECCS) train (i.e. the high pressure injection system). The direct cause is the ignition of hydrogen following its separation from oxygen due to the radiolysis of reactor water. In another instance there was unisolable blowdown of steam to the suppression pool. Similar events had been reported as far back as 1985.


GRS, Germany

Hydrogen explosions in BWR piping have been identified as a recurring event.

Important lessons learnt

The history for some recurring events is up to 20 years. This raises questions as to why corrective actions had not been implemented in a timely manner. Several possibilities exist:

- The operating organisation was not aware of the events or thought that they were not applicable.
- The regulatory authority was not aware of the events or had not imposed timely corrective actions on the licensee.
- Work on the appropriate corrective action was in progress, but not fully implemented.
- The event was considered to be of lesser importance and risk than other plant modifications, and thus was not being pursued as rapidly as needed.
- Overall, the operating experience feedback programme was not fully effective.
- The root cause of the event had not been correctly identified, and thus the corrective actions were not responsive.
- The contributing factors or causes were not appropriately taken into account in identifying the corrective actions.
- What was thought to be a solution was not, or the problem was generic, and what fixed one aspect did not fix all aspects.

It is likely that many if not all of these possibilities play a role in delaying action.

The risk of the recurring events spans a large scale. There is reasonable agreement that the loss of RHR while at mid-loop can be risk-significant, especially if the primary system pressure boundary and/or the containment pressure boundary is open. This was the situation in some cases. In general, making a quantitative risk analysis of recurrence is difficult and may require many assumptions.

There is no rigorous procedure to study reporting systems of operating events that would highlight recurrence. Thus, detection of a recurrent event is largely dependent on the knowledge, memory and expertise of the analyst. One difficulty is that an event may be taking place at several sites internationally, but has not yet recurred within a given country. It is therefore increasingly important for each member country to report all events of safety significance to the IRS system.

Possible avenues for the future

Recurring events are important to safety in that they can indicate deficiencies in the plant safety culture, gaps in the national operating experience feedback systems, loss of continuity in skilled and knowledgeable operations and engineering staff, or lack of attention to design and operational factors such as plant ageing. Due to the fact that national systems may be incapable of detecting recurrence, international activities are required to tackle the problem. The NEA is currently seeking to map effective ways to fight recurrence as part of the CSNI/WGOE programme of work.

One possible remedy for recurrence is wider international dissemination of brief event descriptions extracted from the IRS. Such a description might consist of an abstract; the history of earlier events; direct causes; root causes and contributors; corrective actions; schedule for completion of corrective actions; and safety significance (including risk insights). Circulating this information on a regular basis could prove useful both to the regulatory authorities and to the nuclear utilities.

For minor events, trend analyses may be used to monitor the frequency of component failures or human performance problems, which may indicate weaknesses in plant processes and programmes. Resources to treat this information need to be made available in the plants and the regulatory organisations if the nuclear industry hopes to maintain and further improve its safety and economics. ■

Notes

1. NEA/CSNI/R(1999)19, “Recurring Events”, OECD/NEA, Paris.
2. NEA/CSNI/R(2002)25, “Proceedings of the Workshop on How to Prevent Recurring Events More Effectively, 6-8 March 2002, Boettstein, Switzerland”, OECD/NEA, Paris.
3. NEA/CSNI/R(2003)13, “Recurring Events”, Vol. 2, OECD/NEA, Paris.

Further reading

1. Convention on Nuclear Safety, IAEA, Vienna, June 1994.
2. NEA (2000), *Nuclear Power Plant Operating Experiences from the IAEA/NEA Incident Reporting System, 1996-1999*, OECD/NEA, Paris.
3. IAEA (2003), *Nuclear Power Plant Operating Experiences from the IAEA/NEA Incident Reporting System, 1999-2002*, IAEA, Vienna.