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CSNI Technical Opinion Papers

No. 3
Recurring Events

NEA No. 4388

NUCLEAR ENERGY AGENCY
ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

Pursuant to Article 1 of the Convention signed in Paris on 14th December 1960, and which came into force on 30th September 1961, the Organisation for Economic Co-operation and Development (OECD) shall promote policies designed:

- to achieve the highest sustainable economic growth and employment and a rising standard of living in member countries, while maintaining financial stability, and thus to contribute to the development of the world economy;
- to contribute to sound economic expansion in member as well as non-member countries in the process of economic development; and
- to contribute to the expansion of world trade on a multilateral, non-discriminatory basis in accordance with international obligations.

The original member countries of the OECD are Austria, Belgium, Canada, Denmark, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The following countries became members subsequently through accession at the dates indicated hereafter: Japan (28th April 1964), Finland (28th January 1969), Australia (7th June 1971), New Zealand (29th May 1973), Mexico (18th May 1994), the Czech Republic (21st December 1995), Hungary (7th May 1996), Poland (22nd November 1996); Korea (12th December 1996) and the Slovak Republic (14th December 2000). The Commission of the European Communities takes part in the work of the OECD (Article 13 of the OECD Convention).

NUCLEAR ENERGY AGENCY

The OECD Nuclear Energy Agency (NEA) was established on 1st February 1958 under the name of the OEEC European Nuclear Energy Agency. It received its present designation on 20th April 1972, when Japan became its first non-European full member. NEA membership today consists of 28 OECD member countries: Australia, Austria, Belgium, Canada, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Luxembourg, Mexico, the Netherlands, Norway, Portugal, Republic of Korea, the Slovak Republic, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The Commission of the European Communities also takes 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 friendly and economical use of nuclear energy for peaceful purposes, as well as
- to provide authoritative assessments and to forge common understandings on key issues, as input to government decisions on nuclear energy policy and to broader OECD policy analyses in areas such as energy and sustainable development.

Specific areas of competence of the NEA include safety and regulation of nuclear activities, radioactive waste management, radiological protection, nuclear science, economic and technical analyses of the nuclear fuel cycle, nuclear law and liability, and public information. The NEA Data Bank provides nuclear data and computer program services for participating countries.

In these and related tasks, the NEA works in close collaboration with the International Atomic Energy Agency in Vienna, with which it has a Co-operation Agreement, as well as with other international organisations in the nuclear field.

COMMITTEE ON THE SAFETY OF NUCLEAR INSTALLATIONS

The Committee on the Safety of Nuclear Installations (CSNI) of the OECD Nuclear Energy Agency (NEA) is an international committee made up of senior scientists and engineers. It was set up in 1973 to develop, and co-ordinate the activities of the Nuclear Energy Agency concerning the technical aspects of the design, construction and operation of nuclear installations insofar as they affect the safety of such installations. The Committee's purpose is to foster international co-operation in nuclear safety among the OECD member countries.

The CSNI constitutes a forum for the exchange of technical information and for collaboration between organisations, which can contribute, from their respective backgrounds in research, development, engineering or regulation, to these activities and to the definition of the programme of work. It also reviews the state of knowledge on selected topics on nuclear safety technology and safety assessment, including operating experience. It initiates and conducts programmes identified by these reviews and assessments in order to overcome discrepancies, develop improvements and reach international consensus on technical issues of common interest. It promotes the co-ordination of work in different member countries including the establishment of co-operative research projects and assists in the feedback of the results to participating organisations. Full use is also made of traditional methods of co-operation, such as information exchanges, establishment of working groups, and organisation of conferences and specialist meetings.

The greater part of the CSNI's current programme is concerned with the technology of water reactors. The principal areas covered are operating experience and the human factor, reactor coolant system behaviour, various aspects of reactor component integrity, the phenomenology of radioactive releases in reactor accidents and their confinement, containment performance, risk assessment, and severe accidents. The Committee also studies the safety of the nuclear fuel cycle, conducts periodic surveys of the reactor safety research programmes and operates an international mechanism for exchanging reports on safety related nuclear power plant accidents.

In implementing its programme, the CSNI establishes co-operative mechanisms with NEA's Committee on Nuclear Regulatory Activities (CNRA), responsible for the activities of the Agency concerning the regulation, licensing and inspection of nuclear installations with regard to safety. It also co-operates with NEA's Committee on Radiation Protection and Public Health and NEA's Radioactive Waste Management Committee on matters of common interest.

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FOREWORD

The main mission of the NEA Working Group on Operating Experience (WGOE) is to analyse and develop insights from operating experience, and to communicate these insights to the NEA Committee on the Safety of Nuclear Installations (CSNI), the NEA Committee on Nuclear Regulatory Activities (CNRA) and interested government and industry bodies. In order to be able to do so, the WGOE conducts special studies, workshops and generic assessments in areas of high safety and regulatory significance.

The WGOE also supervises the Incident Reporting System (IRS), jointly operated by the International Atomic Energy Agency (IAEA) and the OECD Nuclear Energy Agency (NEA). Furthermore, the WGOE plays a role in providing advice and assistance in drawing conclusions from several other international databases, such as those for incidents involving fuel cycle facilities (FINAS), computer-based systems important to safety (COMPSIS) and common-cause failures (the ICDE project). A technical paper of this nature is seen as a good way of delivering brief and refined messages from operating experience.

The technical opinions contained herein have resulted from the work of a small task force. Dr. Denwood F. Ross has been the key author of the paper, for which the NEA Secretariat wishes to express its particular gratitude. Several other persons have contributed to the work. Among them, Dr. Michael Maqua (GRS) and Mr. Jorge Tirira (IRSN) have devoted their time to give valuable insights. Mr. Rémy Bertrand and Mr. Didier Wattrelos (IRSN) contributed significantly to the final editing phases of the work. The end product represents the consensus of the CSNI WGOE regarding recurring events in nuclear power plants, for which the working group deserves acknowledgement as a whole.

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RECURRING EVENTS

Introduction

This technical opinion paper (TOP) represents the consensus of CSNI (Committee on Safety of Nuclear Installations) Working Group on Operating Experience (WGOE) regarding recurring events in nuclear power plants. The primary audience for this paper is the plant operations and engineering staff and those parts of the regulatory organisations that are involved in the analysis, evaluation and feedback of operating experience. The paper is intended to provide examples of recurring events to illustrate the safety significance of such events, and to encourage organisational awareness and attention to their prevention and mitigation.

One early example of recurring events is the Three Mile Island (TMI) accident of March 1979, since a similar event had occurred about 18 months before. Over the past years, there have been many observances of recurring events, although of lesser severity than that of TMI.

The NEA CSNI Working Group on Operational Experiences has on two separate occasions produced reports on recurring events. It has also sponsored a workshop on this topic in collaboration with the International Atomic Energy Agency (IAEA) and the World Association of Nuclear Operators (WANO). The workshop and the reports form the basis for this Opinion Paper.

Systems for analysis of operating experience and recurring events

Analysis and evaluation of operational events have been of among the most vital nuclear safety activities for decades. The need to perform this analysis was emphasised recently in the Nuclear Safety Convention, Article 19. The goals of Article 19 are that:

- *programs to collect and analyse operating experiences should be established;*

- *the results obtained and the conclusions drawn should be acted upon; and*
- *existing mechanisms should be used to share important operating experience with international bodies and with other operating organisations and regulatory bodies.*

Consequently, there are many databases of operating event descriptions. For instance, the NEA and IAEA jointly operate the Incident Reporting System (IRS). Industry has, through the WANO, established another system. Each regulatory body has its own national operating experience system. In addition, individual utilities, collections of utilities by reactor type and reactor vendors have systems tailored to individual needs.

The following definition has been adopted 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."

Despite the multitude of systems to collect and analyse operating experience, there does not seem to be one to search in a systematic fashion for recurring events. Hence, the identification of recurring events is done mostly in a case-to-case fashion.

Assessment and examples of recurring events – first CSNI report

The first recurring event report NEA/CSNI/R(1999)19 identified four examples of recurring events, as shown in the box to the right next page.

A recurring event of particular interest for a PWR 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;
- and decay heat is being removed by the RHR system.

Generally, the steam generators may not be available for RHR.

The history of loss of RHR at mid-loop conditions was reviewed. There were over 20 such events in the time period 1980-1996, i.e. more than one per year. The events were widely publicised and there were numerous communications by the regulatory bodies. Even so, this scenario continued to occur even though the corrective actions were well known.

Recurring events from NEA/CSNI/R(1999)19

1. Loss of residual heat removal while at mid-loop (PWR).
2. Failure of valves to operate.
3. Service water degradations due to biofouling.
4. BWR power oscillations.

Another recurring event identified was instability in boiling water reactors. A usual design criterion for boiling water reactors 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. These instabilities were quite large, e.g. with neutron power oscillating between 40 and 90% power. In spite of this, experts generally agreed that the risk attendant to BWR instability is quite low. Corrective actions for these oscillations or instabilities were not well defined and, in some cases, utilities were somewhat surprised when inadvertent instability was experienced.

A third example of recurring events was reduction or interruption of service water due to build-up 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 – second report (to be issued in 2003)

One follow-up action to the first recurring event report was an international workshop on this subject held in March 2002 jointly sponsored by NEA and WANO. This workshop contributed significantly to the second report about recurring events.

The recurring events identified in the second report are listed in the box to the right next page.

Recurring events identified in the second report

1. Loss of 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 ECCS.
7. Service water system biofouling.
8. System level failures due to human factors considerations.
9. Strainer clogging.

Three recurring events identified in this second report were also identified as recurring events in the first report. This lends substance to some of the causes of recurring events – especially to the poor feedback of operating experience.

The loss of RHR while at mid-loop conditions, for a PWR, occurred several times at one facility. In all cases the fluid loss was terminated before adversely affecting the RHR pump. On average it seems that the recurrence rate for this scenario is diminishing, although there is not sufficient elapsed time yet to make a firm conclusion.

Two additional instances (since the 2000 report) of BWR instability have occurred. In one of them, the operating organisation stated that it had not been sufficiently warned about the trend of the plant from very stable to unstable conditions, and thus could not prevent the event. Note that the general view that instability is not particularly safety significant is conditional on detection and suppression of instability.

There was one additional recurring event involving loss of heat sink due to marine biofouling. A four-unit station reported potential loss of heat sink due to a rapidly growing excess of algae that interfered with the circulating water system and resulted in trip of two units. Some condenser circulation continued, but there was a concern about loss of service water or collapse of the travelling screens.

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. At 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 15 years.

Finally, hydrogen detonations have occurred within BWR piping as reported by several stations. In some cases the immediate consequence was loss of ECCS train (i.e., the high pressure injection system). The direct cause is the evolution of hydrogen and oxygen from the radiolysis of water. In another instance there was unisolable blowdown to the suppression pool. Some mechanisms of the event are still under review as of early 2003. Similar events had been reported as far back as 1985.

Important lessons learned from the two reports

It was seen that the history for some recurring events is, at least, up to 20 years. This raises questions as to why the corrective actions had not been implemented in a timely manner. Several possibilities exist:

- The operating organisation failed to take timely action, or was not aware of the events, or thought it was not applicable.
- The regulatory authority was not aware of the events, or had not imposed the licensee to take timely corrective actions.
- 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, in fact, not one or the problem was generic, and what was a fix for one aspect did not cover all aspects.

It is likely that 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, many recurring events have had no attached quantification of risk significance at the time of the event occurrence and report.

Concluding remarks

There is no rigorous procedure to study operating events that would illuminate recurrence. Thus, detection of a recurrent event is largely depending on the knowledge, memory and expertise of the analyst. One difficulty is that an event may be taking place at several sites within the NEA community, but has not yet recurred within a given country. Also, it is possible that an event would not be identified as recurring without a search of an international database. It is therefore increasingly important for each member country to report all events of safety significance to IRS system.

Based on the recent knowledge, there is a wide variation in the perceived risk of recurring events. A more comprehensive view on the significance recurrence is generated through introducing the risk dimension in the event analyses. An event description should consist of:

- event description;
- history of earlier events;
- direct causes;
- root causes and contributors;
- corrective actions;
- schedule for completion of corrective actions;
- safety significance including risk insights.

Circulating this information on a regular basis could prove useful both to the regulatory authority and to the affected utilities.

One possible remedy for recurrence is wider dissemination of event descriptions, likely causes and corrective actions. 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. Human resources to handle this information should be made available by the Licensees and the Regulatory organisations.

Recurring events are important to safety in that they can indicate deficiencies in the plant safety culture, gaps in the national operating experience feed back 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.

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