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NUCLEAR ENERGY AGENCY
COMMITTEE ON THE SAFETY OF NUCLEAR INSTALLATIONS

RECURRING EVENTS

VOLUME 2

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ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

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– 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 (14 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, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Luxembourg, Mexico, the Netherlands, Norway, Portugal, Republic of Korea, 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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Requests for additional copies of this report should be addressed to:

Nuclear Safety Division
OECD Nuclear Energy Agency
Le Seine St-Germain
12 blvd. des Iles
92130 Issy-les-Moulineaux
France

EXECUTIVE SUMMARY

The feedback of operating experience from nuclear power plants (NPP) is intended to help avoid occurrence or recurrence of safety significant events. Regulatory bodies, and utilities operating nuclear power plants, have established operating experience feedback systems since the beginning of commercial nuclear power production. Well-established operating experience feedback systems exist on national and international level. An example of an international system is the Incident Reporting System (IRS) jointly operated by the International Atomic Energy Agency (IAEA) and the Nuclear Energy Agency (NEA). There also are systems maintained by the operating organizations, including the World Association of Nuclear Operators (WANO), and owner groups of different NPP vendors.

Committee on the Safety of Nuclear Installations (CSNI) Working Group on Operating Experience (WGOE; formerly Principal Working Group No. 1, PWG1) carried out a study on recurring events some years ago. This report, published in 1999, highlighted some areas of safety significance involving recurrent events in different NPPs around the world. Based on the important findings of this report, CSNI requested two additional studies:

1. first an international workshop should be organized and second,
2. a task group should be established to develop a second report on the topic and to evaluate the findings of the workshop.

The workshop, hosted by the Swiss Regulatory Authority, HSK, was held in Switzerland in March 2002. It was attended by 32 experts representing the regulatory, nuclear power plant, vendor, and international agency communities. Several insights and recommendations were presented and are integrated in this report with respect to causes of recurring events:

- Operating experience feedback processes had not always been effective, that is, the existing operating experiences had not been effectively applied,
- Actions to be taken were not implemented in a timely manner,
- The root cause was not known, thus the actions taken were not effective in preventing recurrence of an event,
- The contributing factors or causes of the event were not taken into account in defining the actions to be taken.

Several good practices were identified to prevent recurring events. These practices are part of related guides provided by national and international bodies. Some of these are:

- NPPs should analyse recurring events in-depth, in order to identify root causes and contributing factors to prevent further recurrence. The specific factors that failed to prevent recurrence should be investigated and identified (that is, why prior operating experience was not effectively applied).

- For minor events, trend analyses should be performed to monitor the frequency of component failures (which may be unavoidable) or the frequency of minor human performance problems (which may indicate weaknesses in error prevention processes and programs).
- Analysis of external operating experiences from other NPPs should be strengthened to broaden the basis for preventive measures
- Actions taken after events should be assessed regarding their effectiveness in preventing recurrence of similar events.

Subsequent to the workshop, a more detailed search of reports of operating experience, including IRS and other reports from national sources, resulted in the determination of a number of recurring categories:

- Loss of RHR at mid-loop (in the 1999 report also)
- BWR instability (in the 1999 report also)
- PWR vessel corrosion due to boric acid effects
- Hydrogen detonation in BWR piping
- Steam Generator Tube Rupture
- Multiple valve failures in ECCS
- Service Water Failure due to Marine Biofouling (in the 1999 report also)
- System Level Failures with Human Factors Considerations
- Strainer Clogging (sources of emergency injection or recirculation)

Five conclusions were established on the basis of the workshop and the recurring event analysis:

Conclusion #1: Recurring events continue to be revealed, in spite of long histories of gathering and disseminating reports about these events.

Conclusion #2: Recurring events have a wide range of risk significance, from low (or negligible) up to high.

Conclusion #3: There appears to be deficiencies in the evaluation and application of lessons learned from reports on operating experience.

Conclusion #4: Corrective actions to minimize recurring events are straightforward and there is no reason not to implement them at NPPs.

Conclusion #5: CSNI WGOE needs to consider additional efforts to communicate results from its review and analysis of operating events.

Generally, it can be concluded that recurrence will never be totally avoidable. But efforts can be taken to minimize recurrence, especially if safety significant consequences are likely to result. These efforts should be made by all participants by using the national, international, utility, vendors, and regulatory body experience feedback processes.

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1. INTRODUCTION

1.1 General

The feedback of operating experience from nuclear power plants (NPP) is intended to help avoid occurrence or recurrence of safety significant events. Regulatory bodies and utilities operating nuclear power plants have established operating experience feedback systems since the beginning of commercial nuclear power production. Now, well-established operating experience feedback systems exist on national and international level. An example of an international system is the Incident Reporting System (IRS) jointly operated by the International Atomic Energy Agency (IAEA) and the Nuclear Energy Agency (NEA). There also are systems maintained by the operating organizations, including the World Association of Nuclear Operators (WANO), and owner groups of different NPP vendors.

On the regulatory side, the Incident Reporting System (IRS) /1/, which started its trial operation in 1980 and is now jointly operated by IAEA and NEA, is a simple and efficient system to exchange important lessons learned from operating experience gained in NPPs of IAEA and NEA member states. On the utility side, WANO /2/ established a similar system to share operating experiences and event information in 1989 through its operating experience programme. The international organisations organise regular meetings as well as special working groups and industry workshops to review the reported events and to communicate the important lessons learned to the nuclear community.

Despite the considerable national and international efforts to prevent recurrence of events by learning from prior operating experience, recurring events continue to be a matter of concern. CSNI and its Working Group on Operating Experience (WGOE formerly Principal Working Group No. 1, PWG1) requested a study /3/ be performed on recurring events as contained in the IRS and in other reporting systems. This report, published in 1999, highlighted some areas of safety significance where events recurred in different NPPs all over the world.

Based on the important findings of /3/ the WGOE suggested further activities on this topic. The Committee on the Safety of Nuclear Installations (CSNI) approved the proposal of WGOE in 2000 /4/. These proposed activities were two-fold: first an international workshop should be organized and second a task group should be established to evaluate the findings of the workshop and to draw further lessons. The task group consisted of international experts from the regulatory side as well as participants from WANO and industry.

The workshop /17/ had two separate parts. Overall, 14 presentations dealt with the analysis of recurring events in different NPPs and countries, as well as with methods to prevent the recurrence of events by established or developing procedures proposed by NPPs, utilities, owner groups, WANO or regulatory organisations. In general, the presentations were from the national perspective, and did not include a multi country events examination by each member state.

The second part of the workshop included two working sessions where different working groups discussed in detail the various aspects of recurring events. The findings of these working groups significantly inspired this report.

Subsequent to the workshop, a further examination of information from the IRS and from other sources (in the same manner as was done in /3/) was made to identify recurring events from the multi national perspective. This was necessary to supplement those events that were seen to be recurring within a single member state.

This second report summarizes the recurring events for the period 1999-2002, and also focuses on good practices with respect to:

- management of recurring events, and
- processes and procedures to prevent recurring events.

It was seen that some recurring events identified in the 1999 report are still recurring, even after extensive discussion and reporting. It was also seen that some of the recommendations made in the 1999 report were not as effective as desired. These observations, and the observations from the workshop, played an influential role in the conclusions in this report.

1.2 Importance of Recurring Events

A question naturally arises as to the importance of recurring events. There are some important properties and characteristics of recurring events:

a. An event which continues to occur, within the global nuclear family, indicates some failures in the operating experience feedback system;

b. An event which continues to occur can indicate failures or deficiencies in plant safety culture;

c. An event which continues to occur may indicate lack of attention to problems of aging of components, noting that plant life extension is producing older plants;

d. A pattern of recurring events may indicate loss of continuity of skilled and knowledgeable operational and engineering staff.

e. Recurring events may indicate a technological problem which is not fully understood, and needs further research (see for example Section 3.6 of this report, dealing with Hydrogen Explosions in piping)

f. Recurring events may indicate a type of failure which requires extraordinary effort for total prevention of failure (when there are large numbers of components, or many points of vulnerability)

g. For events where human factors are a consideration, the causal mechanisms and contributing factors are not always easy to identify

h. Some recurring events may not get priority attention and resources, if the perceived risk significance is not high.

2. GENERAL OVERVIEW

2.1 Definition of Recurring Event

Recurring events pose a safety concern because of the recurrence, even if the first event did not have significant safety relevance. The recurrence itself indicates a potential safety problem as it shows that the operating experience feedback loop was not effective. This statement may be true for any unexpected recurrence.

Note that it is recognised that there are recurrent events which are expected, like a failure of an electronic card, but that is taken into account in the system design. As long as the expected statistical failure rate of such a component failure is not exceeded, no follow-up action except repair or replacement will be taken. [A rise in the failure rate could indicate a deficiency in the management of aging, or in the maintenance program, as well as inadequate consideration of operating experience.]

Prior to the workshop, the programme committee proposed a working definition of recurrent events as a common basis of understanding. This was done because a fundamental part of preventing recurring events is developing a commonly agreed definition of a recurring event. The proposed definition of recurring events is as follows:

> *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:*
>
> - *Identified but not specified or*
> - *not adequately specified, or*
> - *not implemented, or not implemented in a timely manner by the responsible organisation.*

Note that Generic Events (one failure affects many similar plants), Common Cause Failure (nature of failure affects more than one redundant train), and Ageing (if the ageing-process is within that expected) would normally not be considered as recurring events within the definition provided above. However, in rare cases both generic events and CCF events may fall into the recurring category.

The 1999 report /3/ showed some important findings. The report focused on 4 case studies based on events reported to IRS and various reporting systems. All of these events have significant safety relevance. Some common attributes for these four case studies were identified:

- The problem existed for many years.
- The problem was well documented and distributed to the concerned parties, and was well known by international groups, and was the subject of discussions at various industry meetings.
- Human actions (or inactions) played an important role.

- In some cases, the event sequences are important from a risk perspective, and all cases had at least some risk significance
- For various reasons, the operating experience feedback programmes were not effective in closing the loop and preventing recurrence.

These findings underline that there exist common aspects of recurring events.

The current report builds on the previous 1999 report and evaluates the findings in detail to suggest, based on the presentations on the workshop, ways to close the feedback loop in timely manner.

2.2 Characteristics of Recurring Events

Operating experience feedback programmes exist in most (if not all) of the NPPs as well as in the national regulatory authority organizations. These are normally well established and their procedures are shared with other NPPs, utilities and regulatory authorities at many conferences and working groups as well as through numerous published papers. The main goals of these programmes are the identification of actions to be taken after an event and the identification of measures to prevent its recurrence. In some cases tools have been developed to assist the NPP staff in avoiding recurring failures.

Recurrence of an event usually indicates weaknesses in the operating experience feedback loop. But it remains a question as to whether recurring events should be treated differently from other events. In several important cases the operating organization knew full well what to do but was not diligent in implementing the known corrective actions. This is a breakdown in the operating experience feedback system.

Before a NPP, utility, national or international body can set up measures against recurring events, the recurrence must first be recognised. Without specific methods to identify the recurring nature, the event recurrence may remain unnoticed. Therefore, NPPs as well as national event reporting system should have the ability to extract information from operating experience databases. In addition, the general procedure(s) for event analysis (both utility and regulatory authority procedures) should include the search for these similar events in order to identify the recurrence. The treatment of recurrent events should differ from the generic treatment of events at least in answering the question why the actions taken after the first event(s) were not effective to prevent the following one(s). The answers can be used to implement comprehensive countermeasures as well as to communicate these lessons learned to strengthen the operating experience feedback on plant level, national levels and international levels.

Recurring events have some typical aspects related to the follow-up corrective actions. As indicated in the recurring events definition given above, the actions may not be taken, or not been taken in sufficient time, or the actions may not have been effective. Determining the correct actions to be taken requires, as a prerequisite, the knowledge of the root cause of the related event. The root cause is intended here to be the cause that, if corrected, prevents recurrence or the event.

However, experience shows that correcting the root cause was sometimes not sufficient to prevent recurrence. In some instances, the corrective actions after events were not taken in time to prevent recurrence. The reasons may be related to low priority, or to insufficient resources (both monetary and human) allotted to the corrective actions. In these cases, the identification of recurrence may lead to a different priority for the need and extent of actions to be taken.

Another area of possible causes for recurrence is human factors and organisational issues. In these areas it may be difficult to identify the root cause of the event, and thus devise effective corrective actions.

However, very often a set of contributing factors facilitated the event occurrence, and often these contributing factors can be more easily identified. Therefore, actions taken related to correcting contributing factors may minimise the probability of recurrence. However, they cannot avoid recurrence entirely.

Recurring events can be recurrent related to their (potential) consequences, as pointed out for 4 case studies in the first report on recurring events /3/, or related to their causes and contributing factors. The recurrence of an event may take place in the same NPP, or at another NPP in a domestic or foreign plant. From discussions at the workshop /17/, it appears that the use of operating experiences of other plants, particularly foreign plants, seems to be weak. This was a general finding during the recurrent events workshop. The underlying reason for the effective use of external operating experience is often described as a “this will never happen to me” attitude. This attitude is caused by the thinking that other NPP types, with different manufacturers or different procedures, may make the recurrence of an event highly unlikely in the reviewer’s own plant. One drawback to the reliance on IRS as an external data base is that not all of the national reports find their way into IRS, and there is also some delay, between event occurrence and event report, perhaps on the order of a year or so.

Adequacy of resources allotted to the screening of external event information was also seen as limiting the effective use of experience.

3. SUMMARY OF RECENT RECURRING EVENTS

3.1 General

This chapter contains a description of some events that are considered as recurring. There is also discussion as to the possible risk significance of the several recurring events, as the regulator and operating authority should be basing corrective action on a time scale proportional, in some way, to the perceived risk significance.

Three types of recurring events: loss of RHR at mid-loop; BWR instability; and, blockage of cooling water due to marine life, are common to both /3/ and this current report.

The database for the recurring events discussed in this chapter includes IRS; national reports; the Accident Sequence Precursor (ASP) programs; open literature; and, reports and discussions within WGOE.

3.2 Loss of RHR While at Mid-Loop Conditions in PWR

The previous recurring event report /3/ discussed loss of RHR while at mid-loop. In /3/ there were a total of 22 such events during the period 1980 through 1996. The detailed description of these 22 events made it clear that this is a recurring event.

Since the first recurring event report, there has been one additional report on this sequence reported to IRS. In IRS 7532 there is a discussion of degradation of natural circulation while in the course of reactor draining. While the system was being drained there were indications from the level system that the system level was dropping at the rate of 50 cm/hr. However the operators did not consider this information credible and continued to drain the system. Eventually there were indications of temperature rises at the exit of the fuel elements. It was found that although there was not a total loss of natural circulation there was nevertheless some degradation. The actual level reached approximately the middle of the hot leg nozzles. The report concluded that the operators violated procedures, that there was no written order for use of a non-standard drain line, and that the decision to continue draining where the level drop suggested otherwise was non-conservative. Some root causes included inadequate safety culture, and inadequate operator knowledge. Within this design there have been three prior such events (see IRS 6057 and 6067, at Bohunice).

In chapter 4 of this report, section 4.1-Belgian events, there is a discussion of five instances of spurious draining of auxiliary nuclear circuits and an inadvertent drop of primary coolant level during mid-loop requiring safety injection. All of these took place at the same Belgian plant. Human error seems to be the primary direct cause. In all instances there were deficiencies in some element of the tagging procedures. In some cases, due to the maintenance in progress, there was only one valve isolating the primary system and, when that valve was erroneously opened, a loss of fluid ensued from the primary system. In all cases the fluid loss was terminated before adversely affecting the RHR pump. The regulatory authority performed a risk-based event analysis for these events.

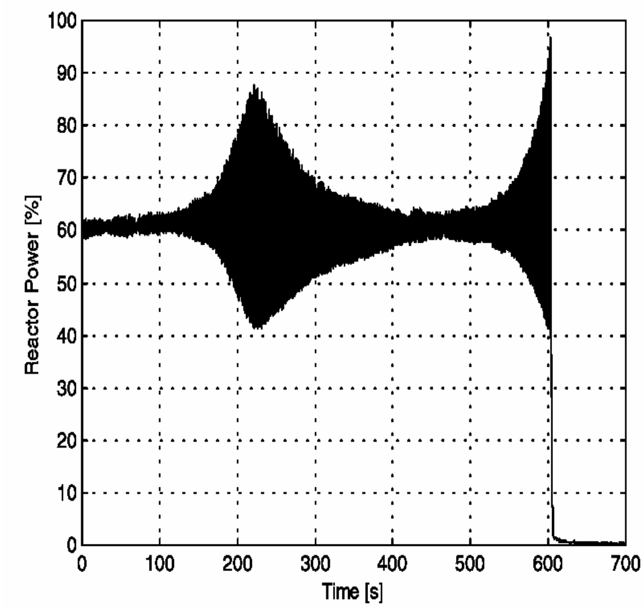
Some shutdown risk studies have suggested that this is a risk-significant event. Chapter 3 of /3/ contained some risk implications. For example, in several cases it was seen that this sequence dominates the shutdown risk values, and that shutdown risk can be an important part of total (operating + shutdown) risk.

Based on the report from Belgium it is seen that this sequence remains classified as a recurring event, but the recurrence frequency for the member states as a whole appears to have diminished. Corrective actions for some member states have been quite forthright: the primary water level is not reduced while the core is loaded, or until a significant delay time has been provided for the fission product heat source.

3.3 BWR Instability

The previous recurring event report discussed nine instances of BWR instability over the period 1982-1995. In a specialists meeting in 1990/5/ there was a consensus that this sequence, although outside the general criteria for BWR operation, did not represent a significant risk.

Since that report there have been two additional instances of instability in Finland (see Chapter 4), additional events in Sweden, and an event at a German plant (Philippsburg-1) in December 2001.



The event in Sweden, which took place in February 1998, was cited in IRS 7330, received November 1999. The plant, Oskarshamn-3, was in a power escalation mode of 60% power and 34% flow rate. An automatic scram occurred due to diverging power oscillations. The picture to the left depicts the power variation during the oscillation. A contributor to this event was the existing power distribution. According to the IRS report, the operating organization had not been sufficiently warned about the trend at this plant from very stable to unstable conditions, due apparently to core optimization loadings. The reactor had no stability monitoring system. During the event the operators continued to operate in an unstable mode, since they had not been adequately warned about the situation.

Reference /11/ contains a complete discussion of power oscillations in Swedish BWRs. From the period 1989 to 2000 there have been seven such instabilities, including Forsmark 1, Ringhals 1, and five events at the Oskarshamn units. In /11/ the recurring event definition used is an event which exhibits common factors with events having previously occurred at the same unit, or at some other unit in the same country, or in different countries. Among other things, there is a conclusion drawn that corrective actions have not been timely or efficient at some of the BWRs. It also concludes that there have been some deficiencies in communication about the causes and corrective actions. Weaknesses in simulator models were noted.

Further, there was some concern that most of the Swedish operational experience may not have been communicated to the international community. Likewise, the report speculates that experience in other countries might not have been reported to the international community.

Reference /10/ describes the current situation in Germany. In November 2001 an in-phase oscillation occurred at Philippsburg 1 NPP, after a feedwater temperature transient. Some of the factors contributing to oscillations include:

- Low leakage loading;
- Spectral shift operation (to control axial power distribution);
- New fuel design with higher enrichment;
- Few control rods inserted; and
- Tighter operational rod lines (less margin to instability).

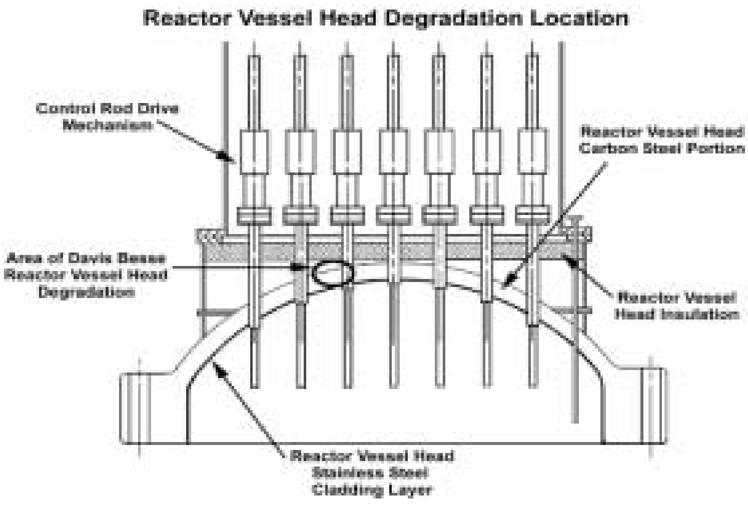
The report concluded that the fixed scram setpoint is sufficient to terminate in-phase oscillations. However, the control system cannot detect on a timely basis out-of-phase oscillations, which might lead to cladding failure (due to deficient cooling). Additional countermeasures are recommended.

A state of the art report (SOAR) /13/ was issued in 1997. It was a very comprehensive report, numbering more than 450 pages. It too suggested that BWR oscillations and instability should not be a safety-significant event, provided that there existed detection and timely suppression means.

There is a high probability that due to more aggressive core loadings and operating regimes these events will recur.

3.4 Materials Problems

There were a number of recurring events associated with materials degradation. Certainly the most significant involved the degradation of the upper head of the reactor vessel of the Davis Besse PWR in the USA. A cavity due to corrosion was discovered in the reactor vessel head during an inspection.



The degraded area covered about 30 square inches where the thick low-alloy structural steel was corroded away, leaving only the thin stainless steel as a pressure boundary. The cavity was caused by boric acid corrosion from leaks through the control rod drive mechanism nozzles, as shown above. The plant may be down for a year or so; a new upper head is to be used.

Leakage through the CRDM area has been a subject of numerous reports to the IRS and has been discussed at WGOE/PWG-1 meetings in the past. Solutions vary, and in some cases plant operators have replaced the vessel upper head.

Boric acid corrosion of the vessel is not new, and thus this is a recurring event. Some prior history includes the following:

- IRS 722, received May 1987, described a severe instance at a US plant of boric acid induced corrosion in the reactor cooling system. There was severe wastage on the exterior of the HPI nozzle, and some wastage on the RCS cold leg.
- A follow-up to IRS 722 described an event at another PWR. More than 500 pounds of boric acid crystals were seen in on the upper head. There were substantial deposits of boric acid found on the vessel head and inside the CRDM. Significant damage was done to three of the head bolts, and additional damage to various components in the upper head area. The source of the boric acid was leakage from a threaded connection of an instrument tube.
- An additional follow-up to IRS 722 was issued in 1988 concerning degradation at yet another US PWR, Salem-2. Some corrosion pits in the upper head were seen, some as large as 1-3 inches in diameter and 0.4 inches deep.
- In IRS 6373, received April 1993, boric acid corrosion was seen on a reactor in Brazil. Almost 300 pounds of boric acid crystals were discovered on the reactor upper head during an inspection. The corrosion was not substantial.

It is observed that in this instance there were two separate elements of recurrence. The leak area, around the CRDM nozzle, had been highlighted by many previous operating experience reports.

The picture at the right shows more detail of the penetration of the upper head by the CRDM. This was copied from IRS 7100.

There were other instances of leakage of borated water from the primary coolant system, as follows:

IRS 1232: This event concerns the Bugey 3 unit (see 7351): In 1991 a leak at the reactor vessel head was discovered during the decennial primary circuit hydraulic test. Damage was found at a CRDM penetration. Subsequent investigation found further cracking in this unit, and in other units. The IRS report in turn cites boron corrosion damage reported in the USA, in IRS 0722 (1988).

IRS 1356: In 1996, Sweden reported on vessel head penetration weld cracks at the Ringhals 2 unit. Some cracking was seen, but no through-wall leakage.

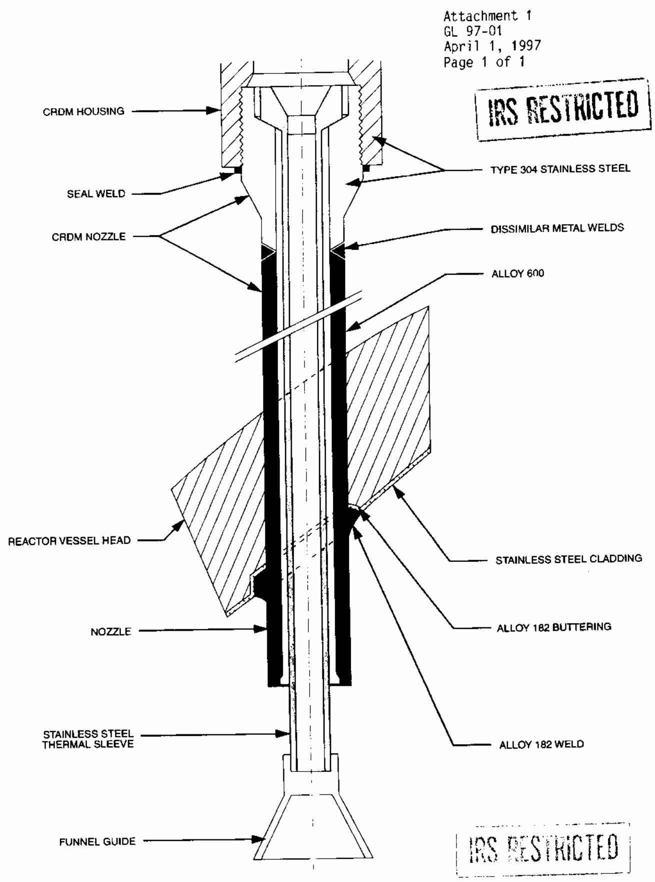


Figure 1. Typical control rod drive mechanism nozzle.
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The regulatory authority, SKI, stated that stress corrosion cracking in the CRGM poses a serious threat to the integrity of the reactor pressure vessel. Corrosion rates on the order of 1 cm/month were observed in the laboratory. SKI took the position that risks of leakage should be preempted, and that suitable measures to this end should be taken.

IRS 1408: In 1994, at the Cabrera plant in Spain, there was a discovery of a boron buildup on an empty CRDM housing. A through-wall crack, 2 cm long, was found. Material damage was linked to a sulfur intrusion some years ago.

IRS 7349: In 1999 there was a leak near some penetration plugs of the vessel head of the Beznau plant. About 15 kg of boric acid crystals were found.

IRS 7351: At the Tricastin plant in France, there was a discovery, in 1998, of a leak at some canopy joint welds near the upper head. Several tens of kilos of boron had been deposited. It was observed that one safety concern was that of corrosion of the upper head, even though the leak rate was below the technical specification limit. Reference was made to a larger leak at Bugey Unit 3, in 1995, where there was serious damage to the outer surface of the vessel head.

IRS 7537: At Paks-2 in Hungary there was an observed deformation of a CRDM nozzle.

Although this did not involve a through-wall crack and leak, there was some significant degradation such that there was an interference with the motion of the control rod drive to a relatively small extent. Somehow fluid leaked into the space between the liner and the nozzle sleeve and then the fluid expanded and caused the damage.

It is believed that the two recurring areas include:

1) The CRDM nozzle leaks had been observed at numerous plants and had been the subject of numerous reports and discussion;

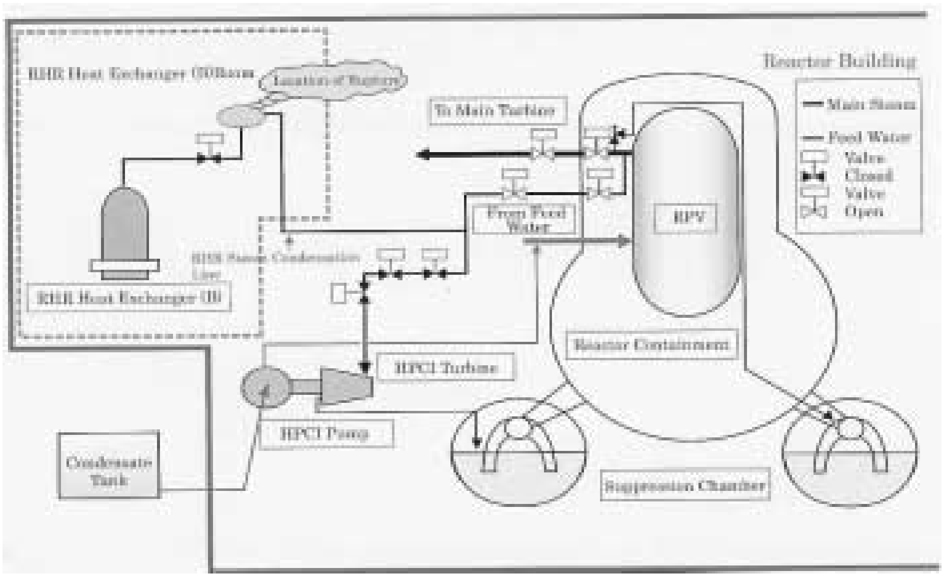
2) The corrosive effects of boric acid were widely known and had been the subject of numerous reports over the past 15 years.

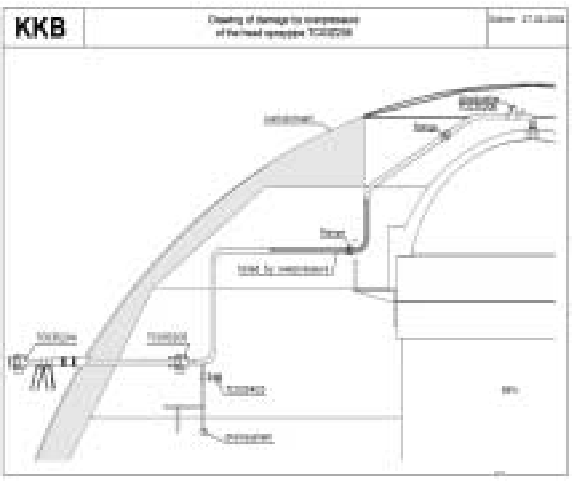
It is clear that there exists an adequate record of warning utilities and regulatory authorities of the concern. One example of a warning by regulatory authorities is contained in /16/. This NRC bulletin, issued one year before the Davis Besse event described above, discusses a history of cracking and leaking at PWR vessel head nozzles. {A number of references are mentioned in this bulletin, dating back to 1990, and earlier.} One particularly useful section of this bulletin is an analysis of the licensing basis, including the NRC General Design Criteria (GDC), with respect to cracking and leaking from vessel head nozzles. Three of the GDC are mentioned (numbers 14, 31, and 32) and it is stated that cracking and leaking are not consistent with these GDC. Several other regulations are also not consistent with cracking and leaking. This bulletin then contains a section labeled Requested Information, which would be used by the NRC to determine whether the license of each plant should be modified, suspended, or revoked (these are standard words that are used by the NRC when making an information request of this sort).

On the basis of this long history of vessel head penetration cracking and leaking it is concluded that this is a continuing recurrent event.

3.5 Hydrogen Detonations

Hydrogen detonations have occurred within BWR piping has occurred recently. In November 2001 a pipe ruptured at the Japanese plant Hamaoka-1, due to a hydrogen detonation. /9/ While operating at rated power, on November 7, 2001, a pipe rupture occurred in the steam condensation line of the RHR. Steam was released into the reactor building. The HPCI was rendered unavailable due to the automatic closure of two isolation valves in the steam supply line. Other safety systems remained functional. Risk estimates detailed in /9/ indicated about a factor of two increase in core damage frequency; however, this design has a very low cdf. Breakage mode of the pipe resulted in the fragments illustrated below.

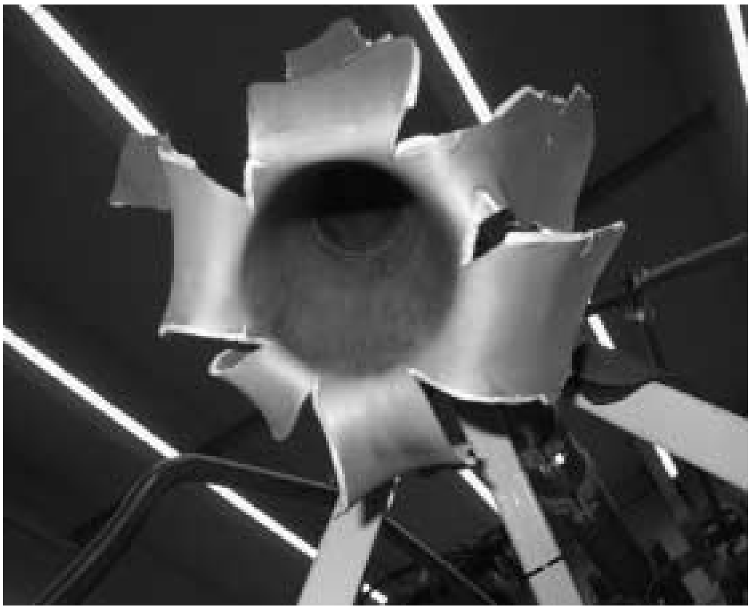




A similar event occurred at the German plant Brunsbuettel, in December 2001. /8/ Hydrogen and oxygen, evolving from the radiolysis of water, accumulated in stagnant sections of piping and eventually reacted explosively. A 2.7-meter section of reactor head spray piping was completely destroyed.

The failure mechanism is still under review but is presumed to be caused by a radiolysis gas reaction resulting in explosion and piping overpressure. As shown in the figure to the left, one check valve, S206, was the pressure boundary between the primary coolant system and the containment.

As shown in the photo to the right, the detonation completely destroyed the pipe.



Previous IRS reports had descriptions of the deleterious effects of the accumulation of hydrogen and oxygen inside pipes, with subsequent ignition/detonation. Some details follow:

- IRS-668: This event, at Forsmark-1 in Sweden, took place in 1985, and was received at IRS in September 1986. Solenoid pilot valves in the automatic depressurization system (ADS) had recurring problems, such as failure to open on demand; long opening time; and, failure to reclose properly. Following a study it was concluded that local combustion events involving hydrogen and oxygen were taking place. The combustion was triggered by the spallation of nickel from the nickel-plating. The fix involved a platinum recombiner. Similar difficulties had been experienced at Finnish plants.

- IRS-756: The Gundremmingen-C BWR in Germany had an event similar to Forsmark. The event occurred in May 1987 and was reported to IRS in August 1987. It was concluded that hydrogen and oxygen, generated from radiolysis, ignited in the connection pipe between the pilot valve and main valve. Damage was done to both valves. One consequence in this event was continued blowdown of the primary system to the suppression pool.

- IRS-840: At another German plant, Kruemmel, there was seen some irregularities in the motion of some safety/relief valves. This event occurred in November 1987 and was reported in April 1988. Again it was concluded that ignition of radiolytic gases had occurred. Platinum recombiner material was added.

- IRS-1437: At the Swiss Muehleberg plant there was a spurious pressure spike in a reference line of the reactor level measurement system. This event occurred in June 1993 and was received at IRS in August 1994. The location of the problem is different from the three events discussed above. The pressure spike was of unknown origin and several hypotheses were made. However, it was not shown that a detonation took place in or next to the instrumentation.

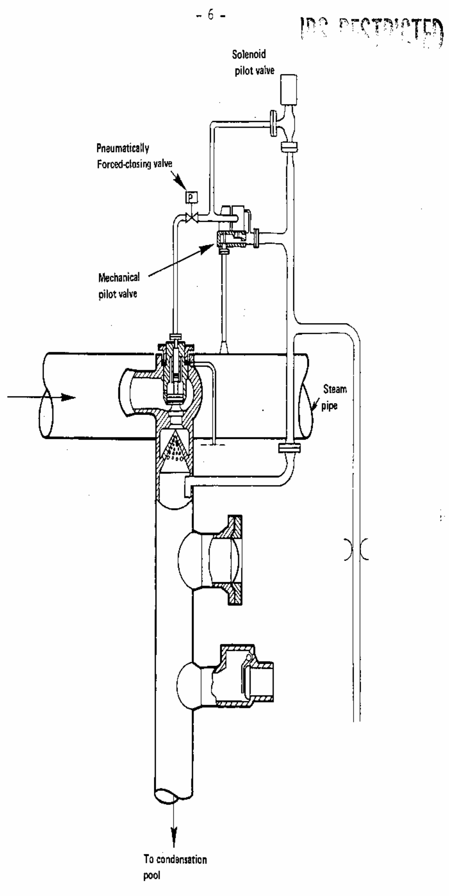


Figure 1. Relief valve of the ADS system

- Although not recurring in the sense that the initiation mechanism and failure modes were different, there have been instances of hydrogen combustion in PWRs for various reasons. For further details, see IRS 1509; IRS 6310, IRS 6314, IRS 272, and IRS 7346.

3.6 Steam Generator Tube Rupture

A number of PWR steam generators have occurred over the past 25 years. Such events are generally classified as moderately risk-important (see Table 3; CCDP approaching 1E-3 is seen). Recently (April 2002) a SGTR occurred at Ulchin-4 in Korea. This plant has been running only three years. Details are not yet available, and there is no IRS report yet.

The USNRC/6/in 1996 issued a summary of steam generator tube experience, worldwide. This report discusses ten steam generator tube ruptures that had occurred, worldwide, as of the report date. Five different mechanisms were listed as causative factors. This somewhat complicates the assignment of a recurrent event category to this event. The report cites the results of level 1 risk assessments performed by a number of plants in the US. The contribution to core damage from a spontaneous tube rupture ranges from 11% of the total core damage probability down to essentially zero contribution. From Table 5.3 it was seen the CCDP for steam generator tube ruptures for several plants was in the vicinity of 1E-3, which is moderately high.

Steam generator tube leaks or ruptures since the publication of /6/ include:

- IRS 7288: In 1998 there was minor leakage from a steam generator tube at the Biblis B plant in Germany. The identified failure mechanism was external tube wall thinning as a consequence of high-velocity cleaning water from a sludge removal process.

- IRS 7266: At the Kola 2 plant in Russia, there was a steam generator tube failure, which was traced to an electric arc welding process during plant maintenance.

- IRS 7388: In 2000 there was a steam generator tube rupture at the Indian Point 2 plant in the USA. The leak rate was about 150 gpm. There were a number of mechanical problems accompanying this transient, and also a number of human factors problems. The exact failure mechanism was not stated in this report.

It is seen that tube failures continue to be recurring events.

3.7 Multiple Valve Failures

A recurrent event involving common failure in the motor-operated isolation valves of the BWR core spray system occurred at Olkiluoto-1 BWR in Finland (see IRS-7477). The difficulty was that a bakelite gear, instead of brass, had been used in the actuator. Unit 2 at this site had similar problems, and some Swedish plants had also experienced difficulty in this area. Hence, this is properly labeled as a recurring event.

The root cause was stated to be deficiencies in the operating experience feedback system. In risk terms, it was thought that there was sufficient redundancy in other systems.

Two additional valve failure events were noted in the IRS. In IRS 7464 (generic; received August 2001) there was discussion of recurring events involving air-operated valves with emergency hand-wheels. It is necessary that the manual operator position be in what is called the "neutral position" in order for the automatic operation to be enabled. In some cases, a wrong setting of the neutral point led to sticking and failure to operate automatically. There are several causes for failure to be in the neutral position, including personnel errors. These valves are in safety systems (for example, containment isolation) and there are a large number of such valves in some plants (at least for those of French design). Further, although the failure mode has been known for some years, it has proven difficult to eliminate completely.

Relevant to this failure mode of air-operated valves, IRS 1548 provides a report of an event in 1993 involving failure due to not being in the neutral point. This report illustrates the long time that it might take to achieve a solution to a recurring event. In this case, identical failure events were occurring for at least six years after the first report. This IRS report mentions that the faulty positioning of the neutral point was first identified in the early 1980s, thus extending the duration of the problem to more than 15 years.

3.8 Loss of Heat Sink due to Marine Biofouling

The previous recurring event report mentioned several cases where connection to the ultimate heat sink was degraded due to biofouling by marine life. Another such instance was reported in IRS 7503(Canada).

The event date was October 2000, and the report was received in May 2002.

Canada reported a potential loss of heat sink due to marine biofouling. The four-unit station had a rapid and excessively large algae run that interfered with the operation of the circulating water system and resulted in trip of two operating units. During this event some condenser circulation continued on other units, but with an excessive pressure drop that could have resulted in loss of service water or collapse of the traveling screens.

3.9 System-Level Failures with Human Factors Considerations

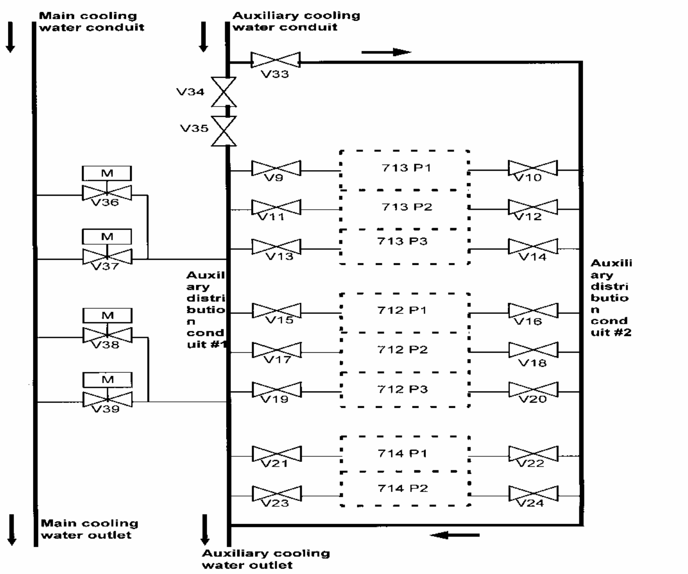
Several events have occurred recently that have a common thread of safety management deficiencies, or significant human errors. These events are not recurrent in the sense that the same event or condition was observed. Rather, it is the causal factors that are recurring. Some examples follow:

- IRS 7433: Short-term Inoperability of all four EDGs at a unit while at full power. (Bohunice-1; Slovakia; occurred September 1999; reported March 2001**)**. While the plant was at full power it was discovered that all four diesel generators were inoperable, as a switch was in the wrong position at each diesel. Restoration was somewhat easy; the proper switch was moved to the correct position. The root causes included deficiencies in communication, in procedures, and in safety culture in general. The station reasoned that this was not a high risk event in that there is a time margin for total station blackout due to the large inventory in the primary and secondary systems. There is a dedicated on-site hydro station, and, there is interconnection capability with Unit 2.

- IRS 7327: Total loss of essential and Auxiliary Service Water Systems. (Barseback-2; Sweden; event occurred May 1999; event reported November 1999). Barseback-2 was performing a periodic test of gate valves associated with essential and auxiliary service water systems. An incorrect line-up of the inlet valves resulted in a total loss of both essential and auxiliary service water. Control room alarms indicated low flow rate in the seawater coolant system. Also, two reactor main recirculating pumps tripped automatically on high oil temperature. The reactor was tripped and the other two reactor circulating pumps tripped, too. The control room directed the field personnel who were performing the operability tests to reverse their last action and open a valve. This restored service water. The system was down only 6 minutes.

Root causes included deficient work practices (not following the step-by-step procedure; lack of clear work responsibility; and, use of a system diagram with the wrong valves circled for action). The total loss of SW is of course of high safety significance. Here, in this event, rapid restoration was possible due to good communications from the control room.

Figure 1: Excerpt from the seawater cooling system



A somewhat similar event was reported in IRS 1326 (event occurred in 1992) and discussed also in /15/. A BWR was in post-maintenance shutdown when the operating staff inadvertently isolated the ultimate heat sing by closing all gates to the inlet bay. Level in the inlet bay decreased rapidly and the running SWS pump cavitated. The emergency SWS pump was started but was stopped due to low discharge pressure. The operators jumpered the tension overload switch and opened an inlet gate, and then restarted the SWS pumps. No specific consequences were attributed to this event. The causes were attributed to personnel error and failure to follow procedures. Some root causes from the inspection report include:

- ❖ Failure to follow the established work control process;
- ❖ Inadequate management oversight;
- ❖ Inadequate communication within and among organizations participating in the work activities; and
- ❖ Insensitivity to shutdown risk activities among the multiple licensee organizations.

- ➢ IRS 1054: Inadequate NPSH for the AFW pumps at HB Robinson PWR (USA). It was reported that due to design deficiencies, there was inadequate NPSH for the three auxiliary feedwater pumps when all were in operation. This discovery was made almost 20 years after the plant started operation. The discovery was made following a plant transient, which resulted in AFW operation, and reduced AFW flow rates were observed. Other plant transients had occurred wherein reduced AFW had been observed. Eventually the AFW system was declared inoperable. Some observations were:

  - i. There was not a common understanding of the design basis document review process, and some questions about the physical arrangement and sizing of the AFW system were not answered. Field data and operational experience were not verified.
  - ii. There was a lack of design basis information on AFW, especially for the condition of all three pumps operating, over a range of inventory in the AFW supply tank
  - iii. The site management failed to act aggressively when a significant deficiency of the AFW system was recognized and reported.
  - iv. Communications to management were less than desired.

This is an example of failure at the system level, involving human factors considerations, perhaps one that could be labeled as involving safety culture deficiencies.

- IRS 746. The BWR in Sweden started some measurements of shutdown margin while the reactor protection system was still in the process of being tested. As a result, the hydraulic scram system was not operable. Control rods could be inserted manually.

  Some comments were made in the report along the following lines:

  i. Excessive overtime was required of the operational staff, and a number of the staff had very little rest.
  ii. Instructions were unclear.
  iii. There were deficiencies in education and training on the technical specifications.
  iv. There were deficiencies in handling of operational orders.
  v. There were deficiencies in auditing administrative orders for safety management.

  In general it was stated that safety control and safety thinking failed on many levels. This is a system level failure (the reactor protection system) with human factors considerations.

- IRS 7303. At a PWR a startup was in progress. The unit was subcritical, and the primary system was being heated by operation of the primary pumps. Pressure was 4 MPa. It was discovered that power was disconnected to the Solid State Protection System. The power had been blocked earlier for a test, but the condition of the system had not been properly noted in the control room documents. As a result, automatic safety injection and feedwater isolation were not available. This is a system level failure with human factors considerations. Some general observations on root causes were:

  i. There were general weaknesses in administrative processes.
  ii. There were weaknesses in management.
  iii. There were weaknesses in human performance.
  iv. There were weaknesses in control room layout.

- IRS 7066. In this BWR it was found that both core spray pumps were inoperable. During a containment leak test the pump motors had been disconnected, and were not reconnected properly. This condition lasted a week or so. It is a system level failure with human factors considerations. Root causes included:

  i. Insufficient system verification.
  ii. Incomplete check of the safety system indications.
  iii. Lack of an information system regarding system operability.
  iv. Procedural difficulties.
  v. Heavy workload and conflicts between personal safety and configuration management.

3.10 The Strainer Clogging Issue

An operational event occurred at the Barseback-2 BWR in Sweden in July 1992 known as a strainer-clogging event. A release of steam washed some debris into the suppression pool and eventually found its way to the strainer at the suction point for a number of safety-related pumps. As a consequence, it was not possible to achieve the design basis flow rate from these pumps. The event description was circulated widely, and most nuclear countries had an action plan to discover whether the phenomenon could recur.

A workshop was held on the issue under CSNI sponsorship in 1994, and two workshops were held in 1999. The results of the last workshops are documented in /14/.

When an event of significance occurs, such as this one, it is usual for the regulatory authority to require inspections of all relevant plants, both BWR and PWR, to determine applicability. Thus it would be expected that the first few years following the Barseback occurrence would show an increase in reporting of similar situations, involving at least the potential for strainer clogging. This is typical, and indeed a number of plants did report certain vulnerabilities. Many BWRs redesigned the strainers, and provided significant increases in strainer inlet areas, in order to reduce the inlet velocity. Some plants replaced the insulation with non-fiber type (reflective metal). Most of the modifications were for BWRs.

However, several reports have been received that describe safety concerns, and the discovery time was seemingly well after sufficient time to have discovered and remediated the deficiency. These events, all from the USA, are:

In September 1996 the H.B. Robinson plant reported (USNRC LER 261 1996 005) that the opening in the sump screen was sufficiently large as to pass debris, which would interfere with proper operation of the ECCS during the recirculation phase. The cause was attributed to lack of control.

In September 1997 the D.C. Cook PWR reported the presence of a fibrous material in an electrical cable tray inside Unit 2 containment. Subsequent investigation revealed that both units had this material, in sufficient quantities to interfere with recirculation. In addition, some deficient coatings were observed. The cause was attributed to inadequate control of materials inside containment.

In July 1998 the San Onofre station discovered (USNRC LER-361 1998 007), during inspection, certain debris potentially could be swept towards the screen. This included tape, tags, placards, and labels. It was thought somewhat unlikely that a sump blockage would have taken place, but the utility thought that the discovery was evidence of ineffective program management.

Recently (November 2002) the Davis Besse PWR reported (USNRC LER 346 2002 005) some safety concerns with the containment sump screen. There was a gap in the screen greater than the ¼-inch design basis, and that there was unqualified paint used inside containment. Potentially there could be a sump blockage. This would interfere with operation of Containment Spray and ECCS. The risk significance of this event is in the process of being evaluated.

4. RECENT EVENTS AS REPORTED BY MEMBER STATES AT THE WORKSHOP

The purpose of the workshop, jointly sponsored by WGOE and WANO, was to provide a forum for presentations and open discussion on the subject of recurring events at nuclear power plants with all professional parties involved, that is, nuclear power plant staff, regulators and technical support organizations.

The meeting discussed insights on recurring events from the operating experience collection, analysis, and use points of view. The workshop provided a forum to explore and map the problem of recurring events and specifically to discuss means to reduce the likelihood of recurrence of events at nuclear power plants both on national and international level. Another objective of the workshop was to provide input for updating the OECD report NEA/CSNI/R(1999)19 "Recurring Events." In the discussions in this section, some of the discussed events have not yet been reported to IRS.

4.1 Belgian events

In Belgium, as in other countries of the NEA community, there is a system of event reporting which flows from the Nuclear Power Plant to the national regulatory authority. Such events are examined for safety significance by both the operating organization and the national authority. In the past (see for example the first recurring events report /3/) there have been examples of degradation or loss of the RHR function during maintenance periods where there was a reduced inventory in the reactor vessel. Such events have occurred recently at one station in Belgium.

Between 1997 and 2001, 5 spurious drainings of auxiliary nuclear circuits and an inadvertent level drop of primary coolant during mid-loop operation requiring safety injection, occurred during outages in the same Belgian NPP. All these events could be linked to tagging process or tagging control deficiencies resulting in the wrong configuration of circuits.

The root causes of these recurring events could be related to several contributing factors.

NPP did not write an internal experience feedback report (incident or event report) when the event had no direct consequences on safety or had no financial impact (linked to a loss of production and to repair costs for example).

Thus the potential consequences on safety are not analysed or insufficiently looked for. The internal operating experience feedback process has to be reviewed in the frame of identifying and selecting events in order to identify recurring ones.

Due to the lack of reporting, the actions discussed with the Belgian regulatory body and decided by NPP after the two first events (1997 and 1998) were not implemented effectively. As a result, two events of the same type occurred during the 2000 outage (there was no outage in 1999) and the third one had exactly the same cause than the 1997 event.

Almost all events happened during outages. This shows that the tagging process during this period presented organisational deficiencies and has to be generally reviewed.

When an event or incident report is written by the NPP, analyses and corrective actions are usually limited too closely to the event itself and to its direct consequences. A more deep and global analysis is required to find the root causes.

The consequences of the most recent event (during 2001 outage) were mitigated due to the corrective actions after the former events of this type. This case shows that the situation can be improved when analysing recurring events and defining corrective actions.

4.1.1 Main conclusions in Belgium

Several conclusions were drawn by the Belgium licensees and the regulatory body that could reduce the number of recurring events. In October 2000 a new organisation chart was implemented in the Belgian NPP, which comprises an operating experience feedback department on each site. There are regular meetings and information exchanges between the two Belgian sites. The operating experience feedback process (domestic and foreign) has been recently described in a general procedure. The new operating experience feedback organisation is too young to draw conclusions, but it seems that it will have a favourable impact to avoiding recurring events.

The main generic lessons learned from the recurring events described above and from further recurring events in Belgian NPP are the following:

The NPP must have a written and auditable operating experience feedback process.

The identification and reporting of events are essential in this process. Without reporting of events, it is of course impossible to analyse them and to find a possible recurrence. The NPP personnel must be encouraged to declare events as widely and freely as possible. To enhance the free flow of information, neither sanctions nor punishment is foreseen in this reporting process. This is also valid for the conclusions of the human factor analysis of events and incidents.

The screening process for the selection of events for in-depth analysis is to be performed by persons having a good knowledge of the NPP history (e.g. to identify the recurrence of events) and of the safety concerns i.e. to identify the real or potential safety significance of events. To reach this goal, the nuclear safety department should be associated to the operating experience feedback process at an early stage.

The Belgian NPP need to improve their analysis of events. Analysis and corrective actions described in the event or incident reports have generally been too closely limited to the event itself and its direct safety consequences. A more deep and global analysis is required to find the root cause of the event and avoiding its recurrence. In some cases, the event should lead to a complete review of a process.

The NPP need to document the corrective actions for preventing recurring events with potential safety impact. The potential consequences and the root causes of the events that had no direct or no significant impact on safety are to be analyses more deeply.

The Belgian NPP need to develop a process able to detect recurrent unavailabilities of safety related equipment. This process can be based on the unavailability statistics already performed by NPP. Nevertheless, the selection criteria have to use the number of occurrences of events instead of the cumulative duration of the equipment unavailability.

The next step is to identify if the same auxiliary equipment or system failures are involving the unavailability of the safety related equipment in order to take definite corrective actions.

4.2 Recent recurring events in Spain

On the recurring events workshop one event was discussed from one Spanish twin-unit PWR. The event was caused by the failure of the secondary neutron source.

During the 1999 refuelling outage high radiation levels were measured during the reactor coolant system de-gasification and clean-up phase. The subsequent chemistry analysis revealed as origin the contamination of the primary circuit with Sb-122 and Sb-124. The contamination was caused by the break of the secondary neutron source. The first actions taken were intended to limit the exposure of the personnel. The reactor core was designed without a secondary neutron source.

The recurrence of the event is related to deficiencies in the implementation of operating experience of other NPPs. Two secondary neutron sources of the same design had broken in two NPPs in 1991.This led to the redesign of the neutron source by the vendor. The new neutron source is double encapsulated. The Spanish NPP had good operating experience with the old design and thus replaced its neutron sources but with the old design. Most other NPPs also continued to operate the sources of the old design at that time.

In the aftermath of the event described the second unit of the Spanish NPP removed its secondary neutron source in the 2000 refuelling outage and redesigned the core. Most other plants have also eliminated the neutron source at this period of time.

The event highlights the difficulties to learn lessons from similar plants related to specific equipment if the same equipment in the own plant has experienced no problems until this time.

4.3 Recurring events in the Finnish NPPs

The Finnish Technical Research Centre (VTT) performed a study on behalf of the Finnish regulatory body on the assessment and development of methods and practices used in the incident analysis in Finland. The final report of the study was published in December 1999. The main objective of the research was to evaluate the adequacy and reliability of the event investigation analysis methods and practices in the two Finnish NPPs and based on the results the development of proposals for further improvement.

On the basis of common deficiencies identified in the event investigation methods in the Finnish nuclear industry organisations the following general recommendations were given:

- The initiating part of event sequences, the originating failures, and causes should be better studied in case of latent failures.
- Analysis of direct causes and errors committed in tasks in which the error was committed, with respect to possible common causes such as deficiencies in work planning or engineering specification should be pinpointed.
- Analysis of common cause failure mechanisms, latent failures and recurrent failures should be periodically performed.
- The analysis criteria on activity, procedure, and human performance related problems are not comprehensive enough. In general, human and organisational factors should be more clearly addressed in the root cause analysis reports.
- Failed or broken defensive barriers (technical as well as organisational) should be more thoroughly surveyed and illustrated.

4.3.1 Recurring events in Finnish NPPs

The Finnish event database was reviewed for the years from 1995 to 2000 to identify recurring events by utilising the existing data and to find out deficiencies in the operating experience feedback practices. In both Finnish NPPs several different recurring events were identified in this time frame. On the basis of the causes of recurrence areas for development were identified in this review both at the practices of the utilities and at the regulatory body. The issues are the same that have already been identified earlier e.g. in the VTT study described above.

Some examples of recurring events identified by the review then extended from 1977 to 2000 are given below with the number of occurrence:

- boron dilution events (6)
- cross failures in safety systems (4)
- pipe ruptures in the feed water system (2)
- blockages related to the water purification system (2)
- control rod drops (12)
- primary coolant leakages (2)
- turbine scrams caused by control system problems (5)
- reactor power oscillations (2)
- open doors to the emergency cooling pump rooms (2)
- fuel assemblies not located in the correct height in the reactor core (several fuel assemblies affected)
- several events indicating problems in the reactor level measurement including one event with a reactor protection activation by level high during shutdown (cause not yet known)
- main recirculation pump trips due to external grid disturbances (3)

4.3.2 Conclusions and recommendations

Based on the review the following causes for recurrence were identified:

- investigation of events was not complete enough
- problems have been identified but corrective actions were not adequate
- corrective actions have not been implemented as planned
- scope of the problem has not been identified
- corrective actions have not been implemented in a safe manner
- corrective actions have not been successful
- corrective actions have not been implemented in time
- direct or root cause was not known

The three last causes were identified in 4 or 5 cases, respectively. VTT summarises that although the review did not cover all reported events during operation of the Finnish NPPs, it is obvious that the most important elements and causes for event recurrence have been identified.

Based on the review the following recommendations were given to avoid the recurrence of events:

Direct and root causes have to be found in order to define and implement adequate corrective actions. This comprises also organisational barriers.

Events should not be investigated as single events. The applicability of the identified root causes should be investigated at different plant modes of operation (e.g. shutdown and power operation) and different plant systems and equipment.

The implementation of corrective actions should be put into practise within short time spans. If suggested corrective actions are not going to be implemented, this should be justified based on plant safety and not for example on the lack of resources.

The success of corrective actions should be assessed periodically.

The identification of recurrence should be included in the event reports.

Event reports should include time schedules for the suggested corrective actions.

4.4 Bulgarian events

The Bulgarian nuclear power plant Kosloduy consists of 4 units of the WWER-440 type and 2 units of the WWER-1000 type. The following event description highlights that similar events in different units of different type can be traced to the same contributing factors.

4.4.1 Loss of natural circulation for core cooling in a WWER-440 NPP

The reactor was in a cold shutdown condition. The core cooling was carried out by natural circulation. Due to a repair at the reactor coolant pump 1 the pump had to be isolated from the reactor. The respective loop was drained. Plant personnel noticed that the pressurizer level dropped. The draining was stopped to check the isolation tightness. A decision was taken to decrease the pressure by opening air vent valves at the pressurizer and at the loops. This procedure resulted in a rising pressurizer level but without decreasing the primary pressure. About 10 minutes later in increase of the primary coolant outlet temperature was detected. The temperature difference between the inlet and outlet temperatures of the primary coolant decreased to 5^o C. The primary coolant temperature rose within 45 minutes to about 130^o C at a primary pressure of about 4 bars. Some 50 minutes later the plant personnel started one emergency high-pressure injection pump to increase the primary pressure. 20 minutes later the core cooling conditions were normalised.

The direct cause for the pressurizer level increase was the presence of a gas volume in the primary circuit. The root cause was the lack of a requirement to evaluate maintenance devices and associated documentation in terms of ensuring nuclear safety during maintenance.

4.4.2 Disturbance of forced reactor coolant circulation in cold shutdown condition at WWER-1000

The reactor was in cold shutdown condition with one ECCS pump operating in residual heat removal mode. The main coolant pump 4 was isolated for maintenance. After installation of a bio-protection inside main coolant pump 4 the pressure on the suction side of the ECCS pump started decreasing. The primary coolant temperature increased from 43^o C to 70^o C. Another ECCS pump was aligned to pump boric solution from the emergency boric solution tank into the reactor. The venting of the isolated main coolant loop 4 was started. While the loop was being vented, the core outlet temperature began to increase. The maximum fuel assembly outlet temperature measured was 106^0 C. The DNB signal (DNBR<10^0 C) actuated the automatic step-by-step program to start the safety systems. Thus the core outlet temperature conditions could be stabilised at 85^0 C. About 3 hours and 10 minutes after installation of the bio-protection it was removed, which resulted in the further stabilisation of the primary condition and the decrease of the core outlet temperature below 70^0 C.

As direct cause for the event it was considered that the documentation of the bio-protection failed to provide sufficient information about the possibility for decreases of the residual heat removal system flow. This resulted in the incapability of the personnel to assess the impact of the bio-protection on the system performance. The operator response was based on previous experience with venting procedures and the alignment of other pumps. The root cause was similar to the other event the lack of a requirement to evaluate maintenance devices and the associated documentation in terms of ensuring nuclear safety during maintenance.

4.4.3 Lessons learned

Although both events resulted in no fuel assembly degradation valuable lessons learned could be drawn. Maintenance activities, in-service inspections and surveillance testing can increase the probability of occurrence of inadvertent events. Two major reasons are arising along similar event analyses: the presence of a large number of people and the incomplete procedures, which do not cover all possible “unexpected” causes for events.

The main lessons-learned are:

1. Procedures had not provided sufficient instructions for adequate operator actions in both cases.
2. Deficiencies in the implementation process of new modifications had been the root cause in both cases.
3. The modifications had added new initiators for events occurring in both cases.
4. The revealing of the direct cause was in both cases of vital significance to bring the conditions under control. The evaluation of the direct cause was performed in situations that were extremely complicated from the communicational and the psychological point of view. This contributed to the long duration of the events.
5. The lessons 1 - 4 should not hinder further modifications but underline that during the implementation of modifications the plant personnel must act extremely responsible.

As a conclusion the following conservative approach related to the implementation of modifications could be suggested:

- It has to be postulated that each modification can add new event initiators or can change the quantities and type of already known initiators an the frequency of their occurrence or create a possibility of well known transients to run in a new, unexpected way that is not described in the procedures.
- The evaluation of such situations has to be performed at the design phase and prior to the implementation of the modification to avoid or to mitigate the consequences from the possible impacts mentioned above.

4.5 French recurring events

In France, the feedback analysis process is carried out following several well-established stages. The main points of the French methodology are:

- The events identification process
- The detection of anomalies with regard to the technical in-service specification
- The proposals of the corrective action to select which of those must be carried out at the level of the nuclear park
- The check of the efficiency of the corrective actions
- Lessons learned

Regarding the recurrence of events, France does not have a specific method entitled "recurring events analysis". However, France does have a well-established method to select, analyse, and prevent recurring events.

Periodically, the IRSN assesses the overall licensee feedback analysis process and evaluates the efficiency of the corrective actions. The evaluation of the IRSN concerns each of the licensee feedback process steps as well as the global operating applicability with the safety involvement.

Further, the IRSN examines in a detailed analysis, *every three years*, the efficiency of the corrective actions proposed by the licensee relative to the most important incidents. These analyses are presented to the French Advisory Group of Experts for Reactors. This group emphasizes periodically the need for the licensee to check each plant in operation on each of the problems treated. This group stresses periodically that the operating experience analysis may need reinforcement in terms of efficiency in actions taken, stressing defence in depth treatment, and root cause analysis.

Due to the specificity of the French nuclear power plant park (58 NPPs of three designs) a certain number of recurring events can be found in the national event database. However, most of them are not of actual safety significance, so the priority may be given to the few most important ones.

Some examples of recurring events in France are given below, without a detailed event description.

4.5.1 Uncontrolled primary level drop at mid-loop operation or during refuelling tasks

Various studies of mid-loop events during shutdown states of operation have been carried out in France. The probabilistic safety analyses showed a significant input on the overall core damage frequency due to a too low primary coolant level.

After several events of this type and taking into account the risk implication important actions were taken in French NPPs. In particular during the transition to mid-loop operation, the licensee must carefully control the primary coolant level. Hardware modifications have been implemented to monitor the primary coolant level, preclude any drop in the level (alarms) and rapidly restore the water level in the reactor coolant system (automatic make-up) in the case of an inadvertent drop. These corrective actions and a reduction of the number of entries at mid-loop and the time allowed for mid-loop operation have led to a reduction of the core damage risk.

4.5.2 Wall cracks at nozzles in the RHR system

Three events with through wall cracks at nozzles in the RHR system occurred in French NPPs within 12 years. The root causes of these events were traced to fatigue. The fatigue cracking of the RHR system nozzles has been studied by the licensee. Some solution were found and implemented in the plants, such as periodic visual inspection and dye penetration tests. Further it was decided to remove any nozzles in safety related systems that are effectively unnecessary and sensitive to vibrations. RHR nozzles have been removed at all 900 MWe series units as they are not operationally used and they are not connected to the nuclear island vent and drain system. For the other nozzles used for instrumentation, venting and draining in the vicinity of regulating valves in the RHR system the licensee has set up a surveillance programme.

More generally, the problem of through wall cracks at small nozzles is of major safety concern since the early 90's in France. This recurring issue and its treatment was examined by the French advisory group during the year 2002.

4.5.3 Events caused by thermal fatigue

Events caused by thermal fatigue have been worldwide reported by several NPPs. The issue is often called the Farley-Tihange-problem after the first two plants reporting this type of cracks. There have also been some French NPPs where cracks in safety systems occurred due to thermal fatigue caused by thermal stratification of the coolant flow.

A French-German working group was established to evaluate the reported events in both countries and to assess the actions taken by the licensees. Main goals of this working group were to better understand the problem and to give recommendations in order to prevent this type of events from recurring.

The recommendations comprised the following to reduce to the risk of cracks by thermal fatigue in unisolable sections of auxiliary systems connected to the primary circuit.

Unisolable sections of auxiliary systems connected to the primary coolant system that could be exposed to thermal fatigue should be identified with respect to the possibility of internal leakage between sections of different temperatures and thus forming unstable stratification.

Measures should be taken to prevent or to mitigate the risk of cracking within these sections like preventive monitoring and maintenance of isolation valves, installation of additional isolation valves, devices for detection of internal leakages, devices for draining internal leakages into vessels or other systems.

The integrity of these unisolable sections should be tested periodically by means of non-destructive testing. This can be done on a sampling basis taking into account the risk and the safety significance of a leak in these sections. For example, large diameter pipes with only one single stop valve isolating fluids of different temperatures are of higher interest than small diameter pipes with at least two isolation valves.

Support elements which could have a significant influence on these piping sections should be checked periodically to ensure that they are kept in their correct position and no inadvertent contact between pipes and neighbouring structures can occur.

4.5.4 Factors contributing to recurrence

During the analysis of French recurring events some contributing factor to the recurrence could be identified.

The modification process in France implicating a large number of units is very long and difficult.

The licensee decided on remedial actions without a deadline for their implementation.

Remedial actions to solve a specific problem were studied and developed. However, an agreement between the licensee and the regulator on the implementation schedule was not reached at the time of the recurrence.

Events were collected and analysed for each NPP but the lessons learned were not disseminated or accounted by the other NPPs.

Organisational and procedural corrective actions are generally preferred to design modifications, which are regarded costly by the licensee. In a long-term point of view, this practice can represent a source of event recurrence, as frequent changes in organisations or procedures may lead to a loss of knowledge regarding the origin of these corrective actions.

4.5.5 French Lessons Learned

Despite the treatment of operating experience events, safety significant events still happen. The average rate of event recurrence remains more or less the same after a period of a few years of operation (between 5 and 10 events per year). It appears that operating experience feedback process and decision-making can take a long time, several years in France, especially if design modifications on safety systems are needed to solve the recurring problem. Periodic review of this analytic general process by both the operators and the safety authority is probably a practical way to improve efficiency in the event treatment and response time of corrective actions.

The identification and the selection of the events to be treated at the level of the French nuclear park are carried out in a methodical, systematic and regular way. Nevertheless, the finding of recurring events indicates that the operating experience process needs improvement in terms of the root cause analysis, defence in depth treatment, and corrective action efficiency.

5. METHODS FOR DETECTING AND COPING WITH RECURRING EVENTS

The workshop produced a number of discussions on national and international approaches to prevent recurring events. Some highlights of these discussions are presented below, and more detail is provided in Appendix A.

Review of the operating experience feedback system.

Several presentations covered the necessity to assess how effectively operating experience is used. The goal is to assure that the review of the system is timely and effective in preventing recurrence.

- There were discussions on reviews of operational events in terms of recurrence, and, in one instance, acknowledgment that there was not a good system for classification of events as recurring.

- In another instance, there was a discussion of a detailed operating experience program. Programs can only lead to long-term effects. Therefore it will take several years to determine whether the program is sufficient to prevent recurrence of undesirable events.

- The role of WANO in recurring events was discussed. WANO hopes to reduce recurring events by, among other things, strengthening the operating experience programs at the nuclear power plants. In addition, WANO is considering the development of a recurring events performance indicator.

- The IAEA discussed a draft safety guide under development that would, among other things, have an objective that corrections are made to prevent recurrence of safety-related events. A coding system was suggested that would enable the trending of recurring system and component failures. They also mentioned the possibility of the development of indicators for the recurrence rate of events.

On the basis of these various national discussions, there appeared to be some consensus on some good practices that could and should be part of an operating experience feedback system:

1. There should be direct briefings by the OPEX group to the operating organization for important event occurrences; simply disseminating a written report may not suffice, and questions and comments by the operating organization on the nuances of an event discussion would be helpful to all;

2. Electronic storage and retrieval of event reports will shorten the time between event reporting and access by the operating organization. This can be particularly helpful when diagrams, photos, and other illustrations are part of the event report.

3. Classification of the relative safety importance of occurring events is important. Several choices are available. In some cases Accident Sequence Precursor (ASP) methods are used. In other cases

some assessment is considered (high, medium, low). If possible, some consistent method would be useful.

4. Management of the utility needs to clearly articulate its expectations about the utilization of operating experience programs.

5. Some method for identifying recurring events is needed, but is not generally available neither in any single member state, nor within the international agencies or utility groups.

6. The database of a single country is not sufficient to identify important recurring events, as the recurrence precursor(s) may have taken place in some other country.

Important points and conclusions identified by the workshop participants concerning recurring events include the following:

- Specific definition of "what is a recurring event" is an important basis needed for responding to recurring events. Definition of the term is necessary to be able to identify when a recurring event occurs. Additionally, a widely accepted definition across all NPPs and regulatory bodies is desirable such that consistent identifications of recurring events are made from country to country. It was generally agreed that a widely accepted definition of a recurring event could then be further revised at a local NPP or regulatory body level to more restrictive criteria to meet local requirements.

- NPPs should be expected to review events from other NPPs, both domestically and internationally, to identify and implement lessons learned from others. The definition of a recurring event at any one NPP should encompass domestic or international events at other NPPs. Here, one has to take into account if it is reasonable to expect that the NPP was aware of the event at another installation (that is, the event was shared via IRS or WANO event reporting systems).

- Event investigation procedures and processes currently used by some NPPs and regulatory bodies may not sufficiently focus on the recurring aspects of events (that is, specifically investigating why actions taken in response to the first event failed to prevent recurrence of the event). Therefore, both the NPP and the regulatory body should have written procedures or defined processes for identifying and investigating recurring events. These procedures or processes should provide additional emphasis and focus on why actions taken after the first event failed to prevent the recurrence of the latter event(s).

- Events that are identified as recurring should be brought to the attention of the plant management team, as often the investigations of recurring events identify possible weaknesses in organisational processes, such as corrective action programmes, carrying out plant modifications, training, and so forth. Additionally, recurring events identified by regulatory bodies should be reported to both regulatory body and NPP management teams.

- Current IAEA/NEA IRS system reporting rules state that if an event is a repetition of a similar previous event, it only needs to be reported if there is "new important lesson learned". As such, the IRS database may be missing a significant number of recurring events, which limits its usefulness to NPPs, regulatory bodies, and researchers.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 Introduction

This chapter describes some conclusions about the frequency of recurring events, their risk significance, role of national systems of operating experience in detecting and correcting recurring events, and the role of CSNI WGOE in detecting and correcting recurring events.

6.2 Frequency of Recurring Events

Conclusion #1: Recurring events continue to be revealed, in spite of long histories of gathering and disseminating reports about these events.

The definition of recurring events is that stated in section 2 of this report, namely:

> *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:*
>
> *Identified but not specified, or*
>
> *not adequately specified, or*
>
> *not implemented, or not implemented in a timely manner by the responsible organisation.*

The 1999 Recurring Events report identified four significant recurring events:

a. Loss of RHR at Mid-loop
b. BWR instability
c. Valve failure due to pressure locking and thermal binding
d. Service water system failure due to buildup of marine life

In the 1999 report it was shown that there were many instances of recurrence over a long period of time, sometimes as long as over 20 years. The solutions were well known, widely published, discussed, and reported to IRS. Thus, they clearly met the above definition of a recurring event.

This 2003 report describes the following recurring events:

a. Loss of RHR at mid loop
b. BWR instability
c. PWR vessel corrosion due to boric acid
d. Hydrogen detonations in piping
e. Steam Generator Tube Ruptures

f. Multiple valve failures in ECCS
g. Blockage of heat sink due to marine biofouling
h. System-level failures with human factors considerations
i. Strainer clogging

Inasmuch as three of the four recurring events discussed in the 1999 report are also on the list for this 2003 report, it follows that recurring events are a continuing concern.

6.3 Risk Significance

Conclusion #2: Recurring events have a wide range of risk significance, from low (or negligible) up to high.

It is sometimes difficult to be precise and quantitative about the risk significance of an event. Where the plant design is well known, and where there has been constructed a plant risk model, then the significance should be able to be quantified. Several countries use what is known as an Accident Sequence Precursor program to quantify the conditional core damage probability, given that certain failures have occurred. In other cases there have been risk assessments results available that quantify the importance of certain scenarios in risk space. But, in general, there is no universal mapping available to assign operational events or conditions to bins of risk significance. Thus, the attribution of “low”, “moderate” or “high” significance has a large degree of subjectivity.

Nevertheless, in the absence of a more precise quantification, it can be useful to assign a coarse risk category for the purpose of determining the degree of urgency in pursuing a solution to the problem. Ideally, one would know the baseline core damage frequency, and the change in core damage frequency that would be suggested by the event in question. These numbers are not generally reported to IRS.

Risk significance of the loss of RHR at mid-loop was discussed in the 1999 report. It was judged to be from moderate to high.

BWR instability, which continues to occur, is judged to be somewhat low in risk significance, provided that oscillations are promptly detected and suppressed. In some cases that were reported, the oscillations were not detected and suppressed promptly, so it is difficult to assess the increase in risk. It is, however, still an event that is outside the design basis for the reactor.

The risk significance of the severe degradation of the reactor vessel upper head has not yet been quantified, but is judged to be rather high.

The risk significance of the hydrogen combustion events and the multiple valve failure events varies significantly.

Steam Generator Tube Failures have been examined in other settings and could be assigned as moderate to high safety significance.

Failure of the ultimate heat sink would be dependent to a large degree on the actual circumstances. The listed event had no risk quantification result, but from the long list of corrective actions it seems that the utility considered this scenario to be at least of moderate risk significance.

Recurrence of an event may result, in part, in gaps in organizational performance. This would not only be difficult to identify in a reliable manner but also difficult to quantify.

6.4 Operating Experience Reporting Systems

Conclusion #3: There appears to be gaps in the evaluation and application of lessons learned from reports on operating experience.

6.4.1 National Systems.

National systems of reporting, along the lines envisioned by the Nuclear Safety Convention, tend to focus on events within the individual member state. If, for example, there were a number of recurring events, but only one per member state, then it is not likely that those events would be characterized by any single member state as recurring. For example, as discussed in Section 4.1, the Belgian authorities characterized loss of RHR while at mid-loop as a recurring event. This had already been characterized as a recurring event internationally, based on more than 20 such events in various countries over the past 20 years.

6.4.2 International Systems—Governmental and Industry

Governmental reporting systems, internationally, consist of the combined IRS operated jointly by the IAEA and the NEA. Industry, in the form of WANO, and various owner and vendor groups, has international systems for the analysis and evaluation of operational data. Both systems collect information from a variety of member states. The IRS usually consists of reports that utilities have made to the national authority, which in turn forwards a subset of reports to IRS.

The WANO reports are more complete, but are considered as proprietary and are not available to WGOE or to the NEA community in general. More than likely the WANO reports are timelier. As noted in Appendix A, WANO is working on some sort of recurring event indicator.

Inasmuch as recurring events continue, even with considerable disclosure of the existence of the events, it can be concluded that there must be gaps in the systems mentioned above, and this justifies Conclusion 3 above.

6.4. Corrective Actions for recurring events

Conclusion #4: Corrective actions to minimize recurring events may be straightforward and should be consequently implemented at NPPs.

In considering this conclusion, it is instructive to review some of the observations on the operating experience feedback system, based on the recurring events:

> Operating experience feedback processes were not effective, that is, the existing operating experiences had not been effectively applied,
>
> Actions to be taken were not implemented in time,
>
> The root cause was not known, therefore the actions taken were not effective in preventing recurrence of an event,
>
> The contributing factors to the event were not taken into account in defining the actions to be taken.

Corrective actions should be responsive to these perceived deficiencies. Some good practices along these lines were formulated during the recurring events workshop, and are listed below:

> NPPs should analyse recurring events in-depth to identify root causes and contributing factors to prevent further recurrence. The specific factors that failed to prevent recurrence (that is, why prior operating experience was not effectively applied) should be investigated and identified.
>
> For minor events, trend analyses should be performed to monitor the frequency of component failures (which may be unavoidable) or the frequency of minor human performance problems which may indicate weaknesses in error prevention processes and programs.
>
> Analysis of external operating experiences should be strengthened to broaden the basis for preventive measures. Emphasis of this effort should be on "what can we learn from the event" that occurred at another NPP, and not on dismissing the information as not applicable.
>
> Actions taken after events should be assessed regarding their effectiveness in preventing recurrence of similar events.

Some analysis and explanatory information for the above good practices follows below.

National and international utility organisations provide tools and advice to help plants organize effective operating experience feedback programmes. However, additional strengthening of the use of this operating experience by NPPs and utility organisations is needed to reduce the likelihood for recurring events. When a recurring event is identified, plant investigation teams should not only investigate causes for the event, but should look further to ascertain why prior operating experience was not effectively used to prevent the recurring event. Corrective actions should be placed to strengthen areas where weaknesses are identified by these investigations. Learning from experience must be seen as a practical way to preclude more serious events and improve plant safety and reliability, and NPP and utility management teams must value "learning".

6.6 Role of CSNI WGOE

Conclusion #5: CSNI WGOE needs to consider additional efforts to communicate results from its review and analysis of operating events.

In the regulatory side community more emphasis should be given to identify possible recurring aspects of events, and to push encourage NPPs not only to investigate aspects of the recurring event, but to further investigate reasons why lessons learned from the prior plant or industry operating experience were not effective in preventing event recurrence. CSNI WGOE and the entire regulatory community should further ensure that corrective actions taken by the plant address weaknesses that contributed to recurring aspects of an event.

Additionally, in order to improve the identification of recurrence in events shared within the regulatory community, it is recommended that IAEA and NEA consider an interpretation to section VI.1 of the IRS Guidelines /1/ which lists three general principles for selecting events to be reported. The third general principle states:

> *"The event is a repetition of a similar event previously reported to the IRS, but highlights new important lessons learned for the international community."*

This general principle should not be interpreted strictly so as to inhibit reporting of an event that seemingly has no new important lesson learned. After all, the very fact that it is recurring serves to illustrate possible deficiencies in the operating experience feedback system, and that is an important lesson in itself.

6.7 Closing Remarks

Generally, it can be concluded that recurrence will never be totally avoidable. But efforts should be taken to minimize recurrence, especially where safety significant consequences cannot be excluded. All participants on the national and international experience feedback processes, utilities, vendors, regulatory bodies, and all other national and international organisations on the regulatory and utility side should make these efforts.

REFERENCES

/1/ IAEA/NEA
IRS Reporting Guidelines; NEA/CSNI/R(97)12.

/2/ Llewellyn, Michael
WANO activities related to identifying and reducing the likelihood for recurring events, Boettstein (2002).

/3/ Ross, Denwood
Recurring Events
NEA/CSNI/R(99)19, 1999.

/4/ WGOE Highlights of the first WGOE meeting (2000).

/5/ IAEA Safety Series No. 93
A system for reporting unusual events in nuclear power plants; Part I A national system; Part II: IAEA Incident reporting system (IRS). 1989.

/6/ International Workshop on BWR Stability. CSNI Report #178. October 1990.

/7/ Steam Generator Tube Failures. NUREG/CR-6365. April 1996.

/8/ Pipe Break in the Area of Reactor Vessel Head Spray System. Report by Kernkraftwerk Brunsbuettel (KKB). March 15, 2002.

/9/ Investigation Report on Pipe Rupture Incident at Hamaoka Nuclear
Power Station Unit-1. Report by Nuclear and Industrial Safety Agency of the Ministry of Economy, Trade and Industry. Japan. July 2002

/10/ Neutron Flux Oscillations at German BWRs. M. Maqua, K. Kotthoff, W. Pointner (GRS). Paper at Eurosafe Conference. 2002

/11/ Recurring Events-Power Oscillations in BWRs. JPB Consulting AB. SKI Report 00:55. December 2000.

/12/ Report of the Task Group Reviewing the Activities of PWG-1.
CSNI/R(2000)13. October 2000.

/13/ State of the Art Report (SOAR) on Boiling Water Reactor Stability. OCDE/GD(97)13. January 1997.

/14/ Knowledge Base for Strainer Clogging-Modifications performed in different countries since 1992. NEA/CSNI/R(2002)6. October 2002.

/15/ Recent Losses or Severe Degradation of Service Water Systems.
NRC Information Notice 92-49. July 2, 1992

/16/ Circumferential Cracking of Reactor Vessel Head Penetration Nozzles.
NRC Bulletin 2001-01.

/17/ Proceedings of the Workshop "How to Prevent Recurring Events More Effectively". Boettstein, Switzerland. 2002.

APPENDIX A
NATIONAL REPORTING SYSTEMS DISCUSSIONS

A.1 Canada: OPEX tools preventing recurring events at the Canadian NPP Gentilly-2

In the last two years Gentilly-2 NPP put in place new operating experience feedback (OPEX) tools to prevent the recurrence of events. The tools were inspired by the guidelines produced by WANO and INPO, but adapted to the specific situation and culture in the plant. The goal for operating experience feedback is to effectively and efficiently use lessons learned from industry and own operating experience to improve plant safety and reliability.

At Gentilly-2, distribution and using operating experience information include following elements:

Review and screen plant and industry operating experience information in a timely manner.

Use criteria to help determine what industry operating experience applies to the plant.

Make applicable industry operating experience widely available to plant personnel in a manner that encourages its routine use.

Distribute applicable industry operating experience to the appropriate personnel for review, analysis, and internalisation.

Trend plant events to identify recurring issues.

Investigate and identify causes of plant events.

Develop, track, and implement actions to correct weaknesses identified by reviews of plant and industry operating experience.

Assess how effectively operating experience information is used.

Share operating experience with the industry to improve the overall safety and reliability of nuclear installations.

The overall effectiveness of the operating experience feedback is reviewed periodically and in response to events. These reviews are performance-based to verify that the actions taken are timely and effective in preventing recurrence. A human factors group defined some performance indicators related to the effectiveness of human performance. These human performance indicators are produced and reviewed quarterly. OPEX performance indicators are produced and reviewed on a yearly basis to improve the OPEX programme at Gentilly-2.

Six special OPEX tools have been developed on basis of the WANO and INPO guidelines:

1. OPEX sheets: The sheets contain information on industry events including the corrective actions taken at Gentilly-2.

2. OPEX review groups: The OPEX review groups consists of several persons from a wide variety of disciplines that review operating experience reports with main focus on the applicability to

Gentilly-2. The goal of this evaluation is to identify the potential plant's vulnerabilities and initiate actions to reduce the potential for similar events at Gentilly-2. The results are communicated via the OPEX sheets.

3. OPEX newsletter: At Gentilly-2, operating experience is written as news stories in a newspaper format that is given to everybody in the plant. This monthly newspaper contains information about internal and external OPEX as well as good practices. An important feature is to request feedback from the readers on ways to enhance the newsletter.

4. Just-in-time briefings: To help personnel internalise operating experience, just-in-time briefings are produced that include plant and industry operating experience information.

5. OPEX website: An OPEX intranet website ensures rapid dissemination of operating experience information within Gentilly-2. All internal and external OPEX reports and the information related to OPEX are available to the plant personnel.

6. OPEX database tools and pre-outage OPEX presentations: There exist to database tools at Gentilly-2. One is specific to maintenance activities and the other one is related to system and equipment information. The results of the research are OPEX related report lists. This effort is easier to support with a searchable database containing both plant and industry experience information during the planning process and then providing this information at pre-job briefings.

A.2 Germany: Integrated event analysis at Gundremmingen NPP

The integrated event analysis is a graduated concept that is built up according to the safety significance and complexity of the events. The structure is based on the structure for dealing with reports received (e.g. failure reports, spurious action reports, external reports, voluntary reports). The integrated event analysis includes the documentation, description, analysis and the evaluation of the results. The resulting reports received are of different origin and come from all areas of the power plant organisation. All reports are processed and evaluated on the basis of a graduated concept, which considers

Routine events (no further analysis necessary),

Simple events within the definition of the integrated event analysis (basic analysis), and

Complex events (in-depth analysis).

The events to be analysed are chosen on the basis of defined selection criteria. This procedure allows a comprehensive and systematic recording as well as evaluation of the events.

The purpose of the integrated event analysis is systematically to record and evaluate all conceivable events. In this case, events are defined as deviations from the nominal status. Additionally, voluntary reports of "near misses" and findings during (simulator) training can also trigger an integrated event analysis.

The selection criteria for events to be analysed comprise operating deficiencies affecting safety related equipment and high value operating systems. The comprehensive list of events to be analysed contains among else accidents, abnormal operating statuses, significant transients, unscheduled unavailability of components with safety critical functions, significant component damages, drop of heavy loads, unintentional release of radioactivity inside or outside the plant, fuel handling events, reportable events that are related to human actions or organisational/administrative issues, information concerning incomplete, incorrect or missing operating instructions, and reportable events associated with maintenance works.

The main goal to collect information and data is to record the plant status and all relevant data before the event, during the event progression or immediately afterwards, and to determine and to document all information available. This process also includes investigations and interviews.

The purpose of the basic analysis and the first evaluation is to ascertain the causal factors based on the information and data gathered. This is done by a team of experts appointed by the plant management. The main goal is to decide whether the plant is in a safe status. The guarantee of a safe plant status is achieved by observing the instructions and conditions operating status concerned. If the safe plant status cannot be guaranteed, corrective measures have to be taken immediately.

An in-depth analysis must be performed, if the basic analysis reveals that interactions between technical, organisational and human factors are part of the related event and the causes have not been adequately determined. The in-depth analysis is carried out by a team of specialists who are familiar with the analysis method. The members of the team come from the competent organisational departments. In some cases, they may be supported by experts with special knowledge in the industrial psychology field. The number of team members is kept small.

The basis for the in-depth analysis is the information and data already collected, the description of the respective event, and of the plant behaviour, the basis analysis and the first evaluation. The purpose of the in-depth analysis is to record the causal factors by breaking down the entire event sequence into individual events (occurrences) and subsequently to evaluate these occurrences with regard to their effect on the entire sequence. Measures aimed preventing recurrence are derived from this information. The in-depth analysis ends with the preparation of the analysis report, which summarises the most important information on the event sequence, the causes and the corrective measures. The technical plant management decides when and by whom which corrective measures will be implemented to prevent any repetition.

The summary of the event process, the effects on plant operation and the results must be fed back to the internal and external experience feedback system. A consistent forwarding of information increases the awareness of employees at all organisation levels and can prevent a recurrence of certain event sequences through the feedback and incorporation of operating experience.

A.3 Westinghouse: Operating experience support from a plant vendor

The main policy of the Westinghouse policy is a process which allows the timely identification, evaluation and reporting of conditions adverse to safety. Due to the US regulation the vendor of NPPs is obliged to communicate to the licensing authority and the affected organisations about failures or non-conformances in products or services that could create a substantial safety hazard. Westinghouse informs also all international customers and licensees of any safety matters that would be reportable to the NRC and customers in the USA.

The Westinghouse process consists of following steps:

Identification of a discrepancy or safety or quality concern

Is a condition adverse to safety potentially involved? If yes, the Westinghouse safety review committee evaluation is initiated, if no, the traditional quality assurance process is followed.

A potential safety issue (PI) is opened.

A detailed technical evaluation is performed.

Licensees, customers and NRC (if required) are notified by a nuclear safety advisory letter (NASL).

The potential safety issue (PI) is closed.

In addition Westinghouse reports also supplemental technical information (technical bulletins) to notify customers of any technical information for installing, maintaining or repairing components or systems within NPPs.

A.4 Sweden: Nordic system for evaluation and information on operating experience feedback in NPPs

Following the Barsebäck event in 1992, when deficiencies in the safety analyses were discovered, the Board of Nordic Nuclear Utilities created a project for co-operation, evaluation, and information concerning operating experience feedback issues in NPPs. The project named ERFATOM started in 1994 and included one manufacturer as well as the control room operator training company.

The main purposes of ERFATOM are:

- Reduce the risk for recurrence of incidents important to safety.
- Make new relevant safety related information, knowledge and recommendations available, with the purpose of preventing the occurrence of safety related events.
- Assure the essential design basis are available when backfitting or enhancing systems and components at Nordic BWRs.
- Exchange experiences between Nordic BWRs and the manufacturer.

The events of the Nordic NPPs are classified in three classes reflecting their impact on safety. For class A events, which has the highest impact on safety, ERFATOM suggests actions to be taken at the NPP and demands a feedback describing the measures performed by the utilities. ERFATOM disseminates the class B and C events to the NPPs without recommendations. The root causes of class B events are analysed, described and the consequences for the respective NPP and the relevance for the other Nordic BWR are reported.

The ERFATOM approach supports the “in-house” procedures for operating experience feedback at the Nordic NPPs.

ERFATOM analyses every issue in terms of recurrence. In the ERFATOM evaluation process information is gathered if a similar event has happened and been evaluated previously. Based on this findings recommendations are given to the utilities to avoid recurrent events. However these evaluations to prevent recurrence are not systematic in the sense that ERFATOM has not yet a toolbox for classification of recurring events.

A.5 UK: British Energy operating experience programme

British Energy is developing its operating experience programme to improve the understanding, attitudes to and use of operating experience at all levels of the organisations, with particular focus on the managerial environment and the follow-through of actions. Several recommendations were given at the beginning of the development. These recommendations comprise the key elements for an effective operating experience programme:

- Expectations of the programme are defined and widely communicated.
- A voluntary reporting programme within a blame tolerant culture.
- Events are analysed using structured methodologies.
- Event root causes and precursors are identified using trained personnel.
- Corrective actions are defined and implemented within agreed timescales.

- Event data is recorded and analysed for trends.
- Lessons learnt are incorporated into training programmes.
- Good practices are recorded and shared.
- Relevant operating experience is included in task preparation and pre-briefs.
- Easy access to operating experience information is provided at the workplace.
- Operating experience is recognised as an essential part of daily work.

These elements provide a platform for continuous improvement in operational and safety performance whilst establishing an environment for creating a learning organisation.

The full deployment of the operating experience programme is scheduled to be complete in 2004. The critical question, "has this prevented recurring events" is not possible to answer at this stage. Early signs indicate that it will, and certainly the programme design has the tools to change the company's culture.

A.6 WANO: WANO activities related to identifying and reducing the likelihood for recurring events

Since its inception, WANO has encouraged members to share operating experience and event information through the WANO Operating Experience Programme. Preventing recurring events is a prime reason for sharing events information. Over 2500 events have been reported to WANO since 1989. As a result of a review on its Operating Experience Programme taken place in 1997, WANO resourced and developed new analysis capabilities and began producing new types of reports for its members. WANO analysis events, writes event reports, provides operating experience-related training, and provides technical support to members to increase their use of operating experience feedback information.

As a result of the 1997 review, WANO began production of several new types of event-based reports to communicate significant industry events. A key focus of analysis of these significant events is whether they are recurring events (that is, very similar to previous events either at that NPP or another NPP). The reports are called Significant Operating Experience Reports (SOERs) and Significant Event Reports (SERs).

The SOERs are written when several event reports indicate that similar issues, or similar aspects or precursors to more serious events, have recently occurred at several WANO member NPPs. SOERs are written in a manner that clearly identifies the issue, describes examples of the issue from various power plant reports, and provides recommendations that each WANO-member NPP is expected to implement at their plant. WANO has communicated to its members that responding to SOER recommendations is considered an obligation of membership in WANO. The effectiveness of the implementation of SOER recommendations is verified through the WANO Peer Review process. Subjects of recurring events described by SOERs to date include:

- safety system status control,
- loss of grid
- unplanned radiation exposures
- severe weather conditions, and
- emergency power reliability.

SERs are written by WANO when a single, highly significant event with important learning points occurs at a member NPP. SERs address single event occurrences, whereas SOERs address issues evident in a series of events. During production of a SER, WANO reviews and analysis possible aspects of the event that may be recurrent. Therefore, even though an SER addresses a single event, some aspects of event recurrence are examined. Where possible, WANO tries to determine why previous operating experience was not effectively used to prevent recurrence of the event. Recent subjects of SERs include

- intake structure blockage results in multi-unit transients and potential loss of heat sink
- highly radioactive particles associated with fuel pool work
- cultural contributors to a premature criticality, and
- BWR core power oscillations.

Recognising the difficulties that WANO members face in processing and using industry operating experience, WANO has adapted and varied its operating experience products to try and offer the right information, targeted to the right person in the utility organisation. Another way WANO is trying to reduce recurring events is through the strengthening of NPP operating experience programmes by technical support missions. Also WANO offers event investigation training courses to its members.

WANO "Just-in-Time Operating Experience" provides specially formatted training/briefing material to assist supervisors, system engineers, work planners, and workers preparing to perform specific plant activities. The briefing material consists of important operating experience and recurring events information for these specific activities. The activities addressed by "Just-in-Time Operating Experience" include many maintenance, testing, and operations activities. A total of 45 "Just-in-Time" briefings have been developed to date.

A future activity being considered by WANO is the development of a recurring events performance indicator to allow measurement and comparison amongst WANO-member plants.

A.7 Activities by NEA and IAEA

The IAEA has developed a comprehensive set of guidelines as safety guides, safety fundamentals, and safety standards to organise the operating experience feedback process on plant, national and, international basis. The Feedback of operating experience is also part of the Convention on Nuclear Safety.

In 1998 the IRS system was revised and is now jointly operated by IAEA and NEA. This revision was the reason to develop a new IRS guideline /1/. Thus, the first part of the old guideline /5/ is now in revision.

Safety Guide DS 288 in development -A national System for the feedback of Experiences from Events in NPPs- will provide guidance on satisfying the safety requirements and will constitute an update and an extension of the Part I of the existing guideline /5/.

The primary objective of an operating experience feedback system according to DS 288 is that no safety related event remains undetected and that corrections are made to prevent recurrence of safety related events. Events that may be regarded as precursors of accidents should also be identified and actions should be taken to prevent any recurrence.

Operating organisations should have the objective of improving safety, plant availability, and commercial performance by identifying the causes of events and thereby avoiding their recurrence and by evaluating the applicability of good practices used by others.

A coding system should be applied that enables events to be characterised. Selected parameters or groups of parameters can then be trended to identify recurring themes. Examinations of these parameters can enable adverse trends to be identified and allow early identification of the potential for recurring events. Types of trending that provide useful information are those that identify:

recurring events from coded events preferably subject to formal investigation;
abnormal trends relating to plant work groups;
abnormal trends during certain operating modes and activities;
recurring system and component failures.

According to DS 288, actions taken in response to events constitute the main objective of the operating experience feedback process to enhance NPP safety. They are aimed generally at correcting a situation, preventing recurrence or enhancing safety. Recommended actions should be aimed at improving human performance, equipment, or managed processes, as for example: modifications to equipment, installation of additional devices, and means to prevent recurrence of the same or similar events.

DS 288 promotes the development of indicators of process effectiveness. These may include the recurrence rate of events. This self-assessed review should evaluate the effectiveness of solving original problems and preventing recurrence.

Despite the development of guidelines, the IAEA organises just as the NEA working group meetings and technical committee meetings on the area of operating experience evaluation mainly on basis of the IRS.

A.8 Assessment method for actions taken after events

The safety of nuclear installation is based on staggered technical measures as well as organisational and administrative measures. An assessment method was developed to make possible a quick and correct assessment of the safety significance of human actions in NPPs. This method can also be applied to assess actions taken after events with respect their effectiveness to prevent recurrence.

The method is based on the INES and probabilistic approaches. The safety significance of human actions is classified into four classes of staggered safety significance. The categorisation is based on the number of effective barriers to prevent or detect a potential faulty human action, the probability of occurrence of the related initiating events, and the maximum possible consequences of these events. The was developed for German NPPs. Although is generally applicable to any NPP, the method has to adapted to other NPPs taking into account the results of the respective probabilistic analyses.

The effectiveness of actions to be taken after events can be performed doing the analysis twice: first, the analysis has to be performed considering the original plant conditions, and second the situation is analysed as if the actions have been implemented. The result of each analysis is the categorisation of the respective human action into one of the four safety classes. The differences between these two analyses can be easily shown, if the respective human action is categorised into a lower class with respect to actions taken compared to the original plant condition. This result would indicate that effective barriers have been implemented to prevent the recurrence of that specific event.

First examples of utilisation of this assessment method show good results for events during power operation. This depends mainly on modelling the time available for countermeasures.