Safety Reports Series
No. 73

Low Level Event and Near Miss Process for Nuclear Power Plants: Best Practices

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LOW LEVEL EVENT AND NEAR MISS PROCESS FOR NUCLEAR POWER PLANTS: BEST PRACTICES

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FOREWORD

The IAEA programme on the operational safety of nuclear power plants gives priority to the development and promotion of the proper use of IAEA safety standards through the provision of assistance to Member States in the application of safety standards, the performance of safety review missions and the conduct of training activities based on safety standards.

A number of IAEA safety standards and nuclear safety publications discuss the processes that need to be put into place for the feedback and analysis of operating experience (OE) at nuclear power plants. These include: Fundamental Safety Principles (IAEA Safety Standards Series No. SF-1), Safety of Nuclear Power Plants: Commissioning and Operation (IAEA Safety Standards Series No. SSR-2/2), Application of the Management System for Facilities and Activities (IAEA Safety Standards Series No. GS-G-3.1) and A System for the Feedback of Experience from Events in Nuclear Installations (IAEA Safety Standards Series No. NS-G-2.11). Additionally, several IAEA TECDOCs cover many aspects of the establishment, conduct and continuous improvement of an OE programme at nuclear power plants, including the consideration of low level events (LLEs) and near misses (NMs).

Although these IAEA safety standards and nuclear safety publications have been in existence for several years, 70 per cent of the IAEA Operational Safety Review Team (OSART) missions carried out at nuclear power plants between 2006 and 2010 identified weaknesses in the reporting and analysis process for LLEs and NMs. In fact, this has been one of the recurring issues most often identified in the area of OE during these missions. These weaknesses have been further confirmed by most of the IAEA Peer Review of the Operational Safety Performance Experience (PROSPER) missions that have been conducted to date. Finally, the IAEA International Nuclear Safety Group, in their report entitled Improving the International System for Operating Experience Feedback (INSAG-23), also determined that learning opportunities from LLEs and NMs are not fully realized.

IAEA Member States have called for guidance on practices for the reporting and analysis of LLEs and NMs. The current publication has been developed to provide insights into leading practices for managers seeking to develop a new — or to improve an existing — LLE and NM process, with the goal of improving safety, production and cost performance.

The IAEA wishes to thank the contributors to the drafting and review of this publication and their Member States for their valuable contributions. The IAEA officer responsible for this publication was S. Fotedar of the Division of Nuclear Installation Safety.

EDITORIAL NOTE

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1. INTRODUCTION

1.1. BACKGROUND

Through the review of industry operating experience (OE), it can be observed that for every significant event, there are a large number of consequential events resulting in limited impact and a still larger number of low level events[1] (LLEs) and near misses[2] (NMs) that result in no immediate loss or damage. This observation is captured in the well known safety pyramid shown in Fig. 1.

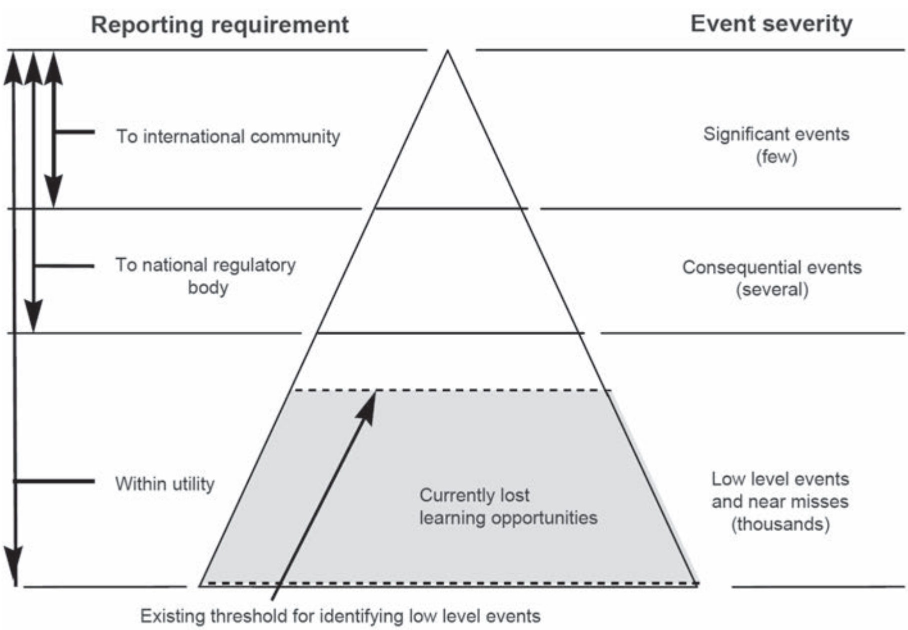

FIG. 1. Relationship between events that affect nuclear safety and other, less significant events.

[1] A low level event is the discovery of a weakness or a deficiency that could cause an undesirable effect but has not, owing to the existence of one (or more) barriers of defence in depth [1].

[2] A near miss is a potential significant event that could have occurred as the consequence of a sequence of actual occurrences but that did not occur, owing to the plant conditions prevailing at the time [1].

Events at the top of the pyramid, often referred to as significant events, may result in injury and loss, have an environmental impact and cause significant disruption of production processes. These significant events are often obvious, are readily brought to the attention of management, and are normally reviewed according to nuclear power plant (NPP) protocols.

LLEs and NMs compose the lower portion of the pyramid. These events have the potential to result in immediate loss, but normally do not. LLEs and NMs are often less obvious than significant events and consequential events, and normally have little, if any, immediate impact on individuals or processes. However, LLEs and NMs provide insight into weaknesses in the defences necessary to prevent higher level events and offer an opportunity to improve safety, production and cost performance.

As numerous significant events illustrate, management failure to capture, understand and remedy LLEs and NMs often foreshadows significant events. Notable examples where NM precursors have been observed but not effectively managed include:

- The 1979 Three Mile Island event, in which an unrevealed fault with the power operated relief valve (PORV) led operators to an inappropriate course of action, resulting in a loss of primary coolant, a partially uncovered reactor core and an environmental release of radioactivity. The Kemeny Commission report revealed that before the event, plants of similar design had experienced problems with the PORVs on nine separate occasions. Weaknesses were also identified in OE arrangements for the investigation and remediation of the accident precursor conditions [2].
- The 1986 Space Shuttle Challenger explosion, in which engineers had identified and reported degraded O-ring seals on previous missions dating back to 1982, with degradation increasing as ambient lift-off temperature decreased. The night before the disaster, management had been warned of the potential for catastrophic failure when lifting off at ambient temperatures of 11.6ºC or less (the lift-off temperature was 2.2ºC) [3].
- The 1999 Paddington train crash, in which 31 people died. From 1993 to 1999, eight NMs, or ‘signals passed at danger’ (SPADs), had occurred at the location (signal 109) where the eventual collision and explosion occurred. At the time of the crash, the signal was one of 22 signals with the greatest number of SPADs recorded [4].
- A primary coolant leak at the Davis-Besse NPP in 2002, which led to significant corrosion of the vessel head and resulted in a quarter inch stainless steel liner becoming the only reactor coolant pressure boundary. A number of lower level precursors, including observable leakage at the reactor vessel head, containment air coolers fouling with increased

frequency, frequent clogging of containment atmosphere radiation monitoring filters with rust coloured boron deposits, and above normal primary coolant make-up rates, had not been adequately reviewed and evaluated via the LLE and NM process. This resulted in significant reactor downtime and had a great financial impact on the utility and a broad impact on the nuclear industry as a whole.

— The 1995 incident at the Bruce Nuclear Generating Station in Canada in which an electrical relay failed to release and a transport trolley (114 t) carrying a fuelling machine loaded with 16 irradiated fuel bundles failed to stop at the designated position. The fuelling machine continued uncontrolled to the physical limits and only came to a stop when the drive motor tripped on overload. Fortunately, although one cable was severed and another was shorted, cooling of the irradiated fuel was not immediately affected; otherwise, the consequences could have been much more significant. There were at least three LLE or NM precursors that could have identified the specific relay problem or the deficiencies in the trolley drive design.[3]

As these examples illustrate, failure to use LLE and NM data to address and correct flawed defences can have catastrophic or highly significant results. Within the context of the nuclear industry, the IAEA and other international organizations such as the World Association of Nuclear Operators (WANO) and the Institute of Nuclear Power Operations (INPO) continually promote the efficient and effective use of a LLE and NM process within the OE field of activity to reduce the possibility of significant events and improve plant performance and safety.

In this publication, best practices for the management of LLEs and NMs are presented, with an emphasis on obtaining operational and strategic value from such events. The premise of this publication is that LLEs and NMs provide information important for accident and event prevention at nuclear facilities, resulting in overall improvements in safety, production and cost performance. This requires well designed processes for identifying, reporting, conducting trend and pattern assessment, analysing, disseminating information about and correcting precursor conditions of LLEs and NMs. This publication is intended to present best practices for LLE and NM arrangements in the belief these practices are widely applicable and can be customized to match the majority of nuclear facilities, and to fit particular organizational and business needs.

[3] INTERNATIONAL ATOMIC ENERGY AGENCY, International Reporting System for Operating Experience (IRS), Report Number 7045, IAEA, Vienna (1997).

1.2. OBJECTIVE

The objective of this publication is to provide NPPs and regulatory organizations with a best practice overview of the development, implementation and continuous improvement of a LLE and NM process in support of the overall OE programme.

As identification of LLEs and especially NMs involves reporting one's own mistakes, senior management plays a critical role in making this happen. This publication covers important issues, such as the creation of a 'blame free' culture, which can help senior management in implementing and operating a successful LLE and NM process in their NPPs/utilities.

To help Member States address IAEA Operational Safety Review Team (OSART) findings and provide additional clarity to NPPs on what is expected of a LLE and NM process, questions typically asked during OSART and Peer Review of Operational Safety Performance Experience (PROSPER) missions for the review of LLE and NM processes within OE areas are also included in this publication (see Annex I).

1.3. SCOPE

Evaluation and in-depth analysis of OE are not restricted merely to lessons learned from safety significant events. They also extend to lessons learned from situations of lower significance or consequence (LLEs and NMs) that had the potential to develop into safety significant events but were prevented from doing so because of plant design features and/or preventive actions by an operator.

Hence, this publication describes the key elements for establishing and enhancing the LLE and NM portions of existing OE programmes. It also contains some examples of best practices available in the industry in this area (see Annex II).

This publication is not intended to describe overall OE programme arrangements, which are already well described in other IAEA publications (see Fig. 2). However, as LLEs and NMs are an integral part of a total OE programme, some references to larger programme aspects are retained in this publication.

Examples of typically unreported LLEs and NMs are provided in Annex III.

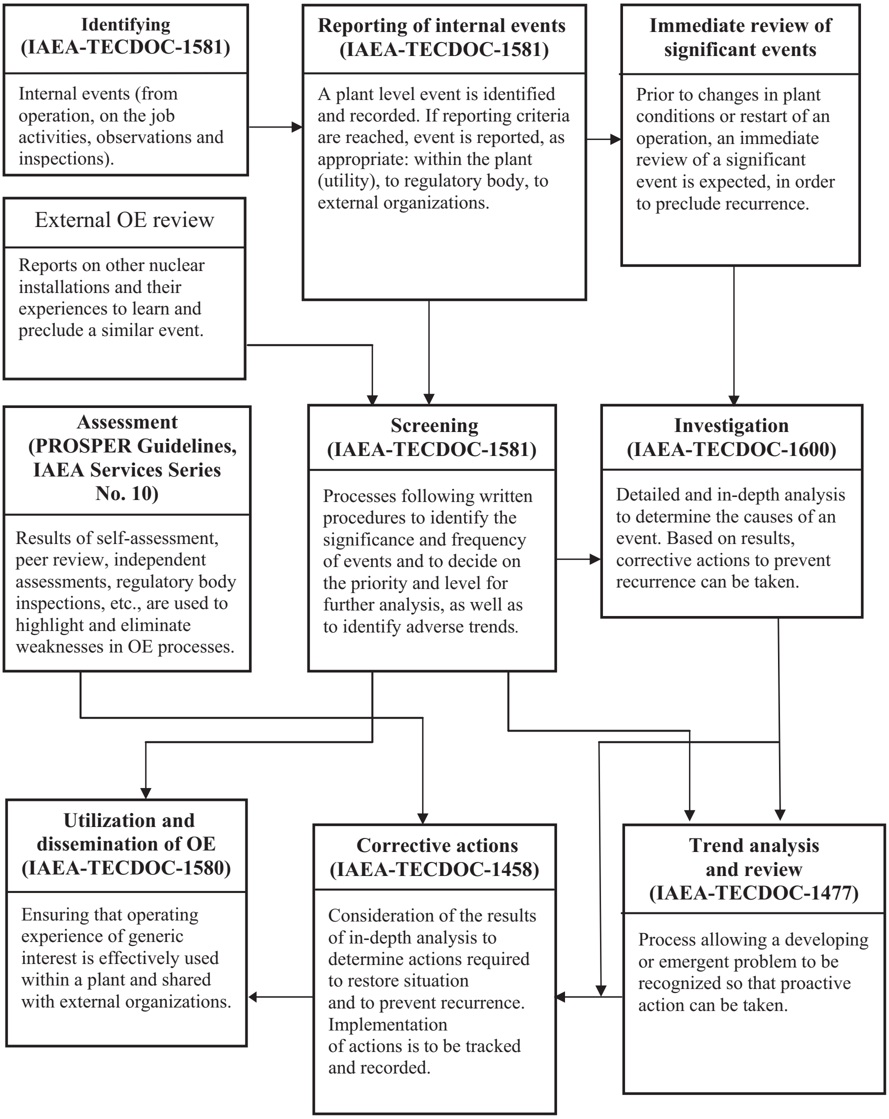

FIG. 2. Typical OE programme arrangements and IAEA publications dealing with its various elements [5–10].

2. ESSENTIAL MANAGEMENT CHARACTERISTICS

2.1. MANAGEMENT OF THE LLE AND NM PROCESS

The IAEA Safety Fundamentals publication Fundamental Safety Principles [11] states that there is a need to establish leadership and management for safety using operating experience feedback to prevent recurrence of accidents and to enhance safety (Principle 3). The IAEA Safety Requirements publication Safety of Nuclear Power Plants: Commissioning and Operation [12] states that "The operating organization shall be responsible for instilling an attitude among plant personnel that encourages the reporting of all events, including low level events and near misses" (para. 5.31). The IAEA Safety Guide on Application of the Management System for Facilities and Activities [13] states that managers and supervisors should encourage and welcome the reporting of potential safety concerns, incidents and NMs, as well as accident precursors, and should respond to valid concerns promptly and in a positive manner (para. 2.18). Additionally, the IAEA Safety Guide on A System for the Feedback of Experience from Events in Nuclear Installations [14] states that OE is to be reported in a timely manner to facilitate learning from events. Furthermore, utilities and NPPs are encouraged to support the collection and analysis of data relating to LLEs and NMs, including those below the threshold for reporting to regulatory bodies (para. 10.4).

Thus, a key role for NPP managers is to ensure that the OE programme includes efficient and effective capture, understanding and analysis of LLEs and NMs, including their trends. This needs to be managed along with the evolution of an organizational culture and continuous improvement programmes in the organization.

Managers set the overall strategy to ensure that a LLE and NM process is established and maintained such that it becomes an essential part of the day to day and long term operation of the facility. Managers also set expectations for the identification and reporting of LLEs and NMs. Their decisions regarding the activities of the OE programme have as their overriding priority the maintenance and improvement of safety performance. The best performing plants maintain an appropriate focus on both LLEs and NMs to eliminate the possibility of more significant events. Managers establish measures of performance to ensure proper engagement in the identification of LLEs and NMs by various departments. They also routinely review overall OE programme performance and, where necessary, provide appropriate direction to correct deviations or shortfalls from desired performance in the LLE and NM process.

2.1.1. Implementation of a LLE and NM process

To implement a LLE and NM process, it is essential to:

- Plan for and make available the necessary resources;
- Develop and implement the process, including required procedure(s);
- Develop a training and retraining plan for process application;
- Communicate and motivate people, and create ownership by all;
- Anticipate dealing with thousands of inputs (e.g. from databases, investigations, screening, grouping by causes, trend and pattern assessment, analysis);
- Provide regular and timely feedback to the persons providing input;
- Follow up implementation, seek feedback and adapt the process, as necessary;
- Consider existing initiatives within an organization when planning implementation.

2.1.2. Continuous direction and oversight of the LLE and NM process

Managers also provide continuous direction and oversight, leading by example in order to ensure that identification, reporting and screening of LLEs and NMs is effective.

In particular, managers:

- Ensure that the concept and benefits of the process are fully understood and valued;
- Develop expectations and goals for the process;
- Ensure that personnel are trained to understand and correctly implement procedures;
- Ensure that the process is simple and easy to understand;
- Ensure that staff are ‘calibrated’ to recognize and report deviations from expected standards in a timely manner;
- Develop and maintain a ‘blame free’ or ‘just’ environment;
- Encourage the reporting of human performance issues;
- Develop a sense of ownership of the process within the NPP;
- Develop inquisitive attitudes and attention to detail;
- Maintain listening attitudes and attention to problems reported by staff;
- Avoid complacency and acceptance of known deficiencies and low standards;
- Enhance standards through continuous improvement;

— Ensure that the process receives wide support;
— Ensure that the process is aligned to generate meaningful results.

Above all, managers ensure that responsibilities and accountabilities for the LLE and NM process are clearly communicated and reinforced as it is introduced and developed.

A desirable additional management objective would be to integrate experience gained from LLEs and NMs into all aspects of NPP operations. This includes such elements as work package planning, task performance, and development of publications and directives.

2.2. CLARITY OF RESPONSIBILITIES AND ACCOUNTABILITIES TO SUPPORT A LLE AND NM PROCESS

At the organizational level, it is necessary that clear responsibilities and accountabilities be established to support the LLE and NM process. In cases where a mechanism for responsibilities and accountabilities is still being established, NPP managers are to ensure that sufficient interim direction and increased oversight are provided.

An OE manager is expected to monitor, on an ongoing basis, the LLE and NM area of OE programme performance and to assess whether this performance meets the NPP's stated objectives. It is up to managers to initiate programme improvements and promote proactive, widespread capture and use of LLE and NM information.

Accountability for LLEs and NMs does not apply solely to the OE manager with primary responsibility for completing OE related tasks. It applies to all managers and team leaders providing cross-functional support to the OE programme. This accountability ensures that necessary support is available and well coordinated, and that the whole organization is aligned to OE programme objectives regarding the reporting and analysis of LLEs and NMs.

The reporting of LLEs and NMs is a vitally important aspect of NPP culture and is strongly influenced by the attitudes of managers and team leaders. Managers lead by example, reporting LLE and NM issues where appropriate. Leaders understand the importance of a thorough LLE and NM process, and encourage the participation of personnel, using every opportunity to motivate people to report — for example, through discussion during meetings, plant tours, training sessions, pre-job briefings, debriefings, bulletins, posters, site newspapers and the intranet.

Within high performing plants, all organization employees take responsibility for their own behaviour and are committed to improving themselves as well as the tasks and work environment. In some organizations, managers have used generic accountability ladder models to communicate and reinforce such responsibilities among their staff (see Annex IV).

With regard to the LLE and NM process, the goal is for individuals to exhibit the following behaviours:

— Freely report LLEs and NMs within an OE programme;
— Communicate to create a shared understanding of LLEs and NMs;
— Regularly apply lessons learned from LLEs and NMs to improve performance.

2.3. CONTINUOUS IMPROVEMENT

Managers often drive continuous improvement through self-assessment processes or periodic external evaluation and review against industry standards and best practices (such as IAEA OSART and PROSPER missions, WANO peer reviews, or INPO assessments). The approaches to such improvements will depend on an organization's maturity (see Annexes V and VI). While an OE programme is wholly dependent on information flow, the Westrum model [15] is particularly relevant to a culture of open reporting and sharing of information, and to the fostering of a 'blame free' or 'just' environment. The leadership of managers in establishing openness in the reporting culture is fundamental to the success of a LLE and NM process.

2.4. CREATION AND FOSTERING OF A 'BLAME FREE' OR 'JUST' ENVIRONMENT

Most LLEs and NMs are caused by error prone circumstances (for example, work places, work practices, environment, job pressure) rather than error prone workers. Studies show that almost all industrial events are rooted in latent organizational weaknesses rather than human error. Managers must remember that people do not intend to make errors, and that most people want a 'blame free' or 'just' environment that treats people fairly, honestly and with respect.

Reference [16] provides a model that can be used by managers to help determine both the level of culpability (accountability) shared between individuals and the organizational weaknesses related to events (see Annex VII). Some NPPs use versions of the model in conjunction with their investigations of human performance events. The model helps managers to identify the prevalent individual or organizational factors that contributed to the event. The model supports the fair and consistent application of performance coaching — or discipline, if appropriate — across all departments and work groups.

In one example, Naviair, Denmark's air traffic service provider, observed that after a change in the reporting requirements and the law in Denmark, which made non-punitive confidential reporting possible for aviation professionals, the number of NMs (separation losses between aircrafts) reported rose from approximately 15 to between 40 and 50 a year two years after the change was implemented (see Annex VIII).

Thus, an important role for managers is to create a positive environment in which personnel feel comfortable reporting LLEs and NMs without undue concern about a punitive response from management — a so-called blame free or just environment. Failure to do so can result in decreased performance, including reduced reporting of LLEs and NMs due to a deterioration of trust between workers and managers — the so-called blame cycle [16]. Safety policies are intended to actively encourage effective reporting and, by defining the line between acceptable performance (often unintended errors) and unacceptable performance (such as negligence, recklessness, violations or sabotage), provide fair treatment to those who report.

Often, low level human errors are not self-revealing, except to the individual who committed the error. Consequently, such errors may not be accessible for analysis if they are not reported, and a wealth of information may potentially be lost. To maximize the benefit from LLE and NM information, it is important that managers foster an environment in which such information is captured. Major advantages in capturing LLE and NM information from staff are that:

- Since nothing serious happened in the reported LLE or NM, a free discussion about the origin of the event is possible with the staff involved.
- The person who made the error may share knowledge about the causal factors behind LLEs or NMs resulting from non-human error. Causes can be evaluated for applicability with input from the individuals who discovered the issue.

It is important that NPP managers continually reinforce expectations for open communication, encouraging staff to look for ways to learn from the reporting of LLEs and NMs. Staff also need to recognize that the process includes an element of personal responsibility and accountability.

Managers are also encouraged to periodically assess the 'blame free' or 'just' culture through the use of anonymous surveys, which staff can voluntarily participate in.

2.5. REWARD AND RECOGNITION STRATEGY

Ideally, managers will give the topic of LLEs and NMs a high profile and provide individuals with timely positive reinforcement for identifying, reporting and learning from their own or others' errors. Typically, in high performing plants, a reward and recognition system is established and applied in a way that motivates the reporting of LLEs and NMs by all personnel and contributes to building a low-threshold reporting culture. This does not necessarily mean financial reward; often, staff members who report LLEs and NMs respond well to praise for sharing their actions among their peer groups.

Some organizations operate an employee of the week/month scheme where the name and photo of the staff member are published at the plant (sometimes called a 'good catch' scheme). Others award plaques or shields to the best reporting division or department. Some plants award certificates to those individuals with the best safety submissions on an annual basis. Other plants use a lottery scheme wherein people who have made a significant contribution to the LLE and NM process or who have identified a significant safety related precursor are entered into prize lotteries, with drawings held quarterly, biannually or annually. Examples of prizes include vouchers, dinner at a local restaurant or event tickets.

2.6. MAINTAINING A POSITIVE REPORTING ENVIRONMENT

Once the basic framework of a LLE and NM process has been established, a major role for managers is to foster an environment in which staff members are comfortable with the process. The reporting of slips, lapses and errors with no or only minor consequences is a complex area in which human emotions play a key factor. Pride, embarrassment, and fear of criticism and possible ridicule by managers, peers and subordinates are real issues for staff involved in LLE and NM reporting. For these reasons, it takes time to build up the trust and confidence of staff. NPPs often avoid including workers' names in reports of LLEs and NMs, and take steps to remove any names, where applicable, by using position titles or other anonymous wording.

Managers' responses to and actions taken regarding events, including LLEs and NMs, will determine how successful the process is. In this respect, it is essential to clearly communicate and reinforce expectations, as well as to maintain a consistent approach. The saying that "reputations take a lifetime to build but only seconds to destroy" is never more pertinent than in this field of a manager's activities.

There are many examples, if not reported then certainly experienced, where managers spend years building an OE programme and staff confidence in LLE and NM reporting only to destroy any staff confidence gained by a single inappropriate response to a particular event. This can happen when a manager asks, 'Who did that?' rather than, 'How did that happen?', or worse still, when he or she takes punitive action rather than seeking to understand what happened and why. Additionally, failure to appropriately reinforce good behaviours and actions can harm an open reporting culture.

Clearly, the nature of an event or a staff member's action will have a defining influence on management's response. However, managers always need to step back and ask themselves, "Is our investment in the potential long term benefits of the LLE and NM process worth jeopardizing for our instinctive reaction to this one event?"

Again, Reason's model [16] can be used by managers as an aid to determine the level of culpability (accountability) shared between individuals, and the organizational weaknesses related to events (see Annex VII).

2.7. MAINTAINING LONG TERM GOALS

Managers in the nuclear industry face many scientific, technical and personnel related challenges. But none is more pervasive than the continual pressure of financial support. In this respect, managers continually seek greater efficiency when perceived non-core business activities come under increased focus.

The objective of an OE programme, and in particular the LLE and NM process, is to prevent significant events by using a systematic approach to latent error identification and reduction. However, some OE practitioners would be hard pressed to express and share a definitive example of where they have clearly achieved this objective. Thus, the OE programme is often viewed as an act of faith and, as such, difficult to support by NPP managers, who are hard pressed to maintain regulatory standards, engineering upgrades and production within tight financial constraints. A short term view to rationalize OE support can be a very tempting proposition for a manager, but each decision must be fully assessed. It is essential that managers recognize the long term benefits of LLE and NM process activities.

High performing plants have experienced considerable success in reducing the frequency, severity and consequences of events within short periods of time when a strong focus has been put on learning from LLEs and NMs to prevent higher level events.

For example, a utility in the United States of America (USA) reduced the number of consequential errors from 3.4 to 0.07 per 10 000 work hours within an 18 month period (see Section II–2 of Annex II). A direct contributor to this success was the focus on learning from LLEs and NMs to prevent errors and accidents of greater consequence. Examples of success using equipment trend analysis in an NPP are detailed in Annex IX.

Additionally, a US study has shown that, on average, each consequential error costs approximately US $110 000 to address and correct (see Annex X). More significant station events can cost an NPP much more. Thus a strong LLE and NM process greatly contributes to improved safety and performance and to real bottom line cost savings in the long run.

3. STAFF SELECTION AND TRAINING

3.1. STAFF SELECTION

Managers are to ensure that adequate numbers of suitably qualified and experienced staff are appointed to oversee the defined scope of the OE programme, and that they are supported at the highest levels of the organization. High priority is to be given to the appointment of knowledgeable and respected staff to key OE programme posts to ensure that managers, as well as engineering, training, operations and maintenance staff, acknowledge and support OE programme activities.

Best practices indicate that staff who are familiar with plant operational practices and procedures, plant systems and management processes, and who are already key plant staff, are most successful in an OE role. Better performing plants allocate full time staff to oversee the OE programme and ensure that the appropriate levels of quality and consistency are maintained. Considerable investment is made in the selection of staff having appropriate analytical skills and the soft skills necessary to exert appropriate influence on all site staff (from management to front line operators) with respect to the LLE and NM process. If necessary, appropriate personal development and coaching opportunities can be made available.

The LLE and NM process has the potential to generate thousands of reports, all requiring database input and trend and pattern analysis. Additionally, any adverse trends identified will require investigation. Managers are to ensure that an adequate number of staff members are trained in the LLE and NM process as well as in event analysis techniques. This extends to staff beyond those dedicated to the oversight of the OE programme to those in operation, maintenance and engineering functions, to ensure that there is a wide base of knowledge concerning the techniques. Best practice indicates that such trained staff routinely apply this training so that skills are maintained. Managers are responsible for keeping an appropriate number of staff available for these activities.

3.2. STAFF TRAINING IN THE LLE AND NM PROCESS

During initial implementation of the LLE and NM process, operations and maintenance staff frequently challenge the value that is added, often stating, ‘It is my job to recognize and fix these types of problems.’ Therefore, training for all staff needs to focus on the longer term systematic and proactive nature of the process, to be explained via trend and pattern analysis, and it is better to direct staff away from the more reactive style of ‘It broke and I’ve fixed it’ thinking.

Managers need to ensure that all plant staff are trained to fully appreciate the benefits of reporting LLEs and NMs, and to understand that their active participation is expected.

Examples of training topics for OE department managers responsible for the LLE and NM process include the following:

- Management and improvement of the LLE and NM process;
- Trend codes (the use of codes to identify and analyse the causes of trends);
- Cause analysis methodologies;
- Statistical analysis tools used for trend data;
- Human performance training, to include organizational contributors;
- Self-assessment of the health of a LLE and NM process;
- Development of a strong self-reporting culture;
- Creation of a database on good practices and pitfalls.

Examples of training topics for OE staff and other departments’ OE coordinators include the following:

- LLE and NM process steps;
- Training in plant operational practices and procedures, plant systems and management processes, and familiarization with key plant staff;
- Trend codes — detailed training;
- Cause analysis methodologies — detailed training;
- Statistical analysis tools used for trend data — detailed training;
- Corrective action development;

— Performance indicator development for a LLE and NM process;
— Human performance training — detailed training;
— Programme effectiveness/self-assessment of the health of a LLE and NM process;
— Accessing a database — good practices and pitfalls.

Training sessions are an important focus area for managers to establish and maintain the correct balance of reporting for their nuclear power plant, both initially when a LLE and NM process is being set up and routinely during staff refresher training. It is necessary that this training include reviews of recent examples of significant, consequential events, as well as LLEs and NMs (possibly using external OE examples). Such an approach is particularly effective in maintaining focus on what is appropriate to report regarding LLEs and NMs.

4. CRITERIA AND THRESHOLDS FOR THE IDENTIFICATION AND REPORTING OF LLEs AND NMs

4.1. CLEAR AND CONSISTENT REPORTING THRESHOLDS ARE ESTABLISHED AND COMMUNICATED

Managers establish and communicate expectations on the threshold for identifying and reporting events. Experience shows that the causes of significant events are usually the same as those of LLEs and NMs. Therefore, it is important that the identification and reporting threshold be established at an appropriate level of detail to identify any unwanted or undesirable situation, or any unintended occurrence (including NMs), which may be useful in preventing reoccurrences and improving plant and personnel safety, reliability and performance.

It is imperative that the identification and reporting threshold for LLEs and NMs be set as low as practically achievable. Ideally, the LLE and NM process will include issues identified in any of the following key areas: plant systems and equipment, human performance and organization/administration (including documentation or processes).

At better performing plants, reporting thresholds may include a full spectrum ranging from day to day plant defects, event reports and NMs through to accidents. The advantage of this type of arrangement is that all data can be contained within one database, allowing for extensive and consistent trend and pattern analysis.

In many organizations, difficulties exist in deciding what should be included in the LLE and NM process or in other existing processes such as work management systems or observation programmes. The examples in Table 1 are meant to help clarify what typically does or does not meet the LLE and NM reporting threshold.

TABLE 1. EXAMPLES OF REPORTING THRESHOLDS FOR LLEs AND NMs

Possibly below reporting threshold	**Likely meets reporting threshold**
Single light bulb failure in office area	Emergency light bulb failure in office area
Expected oil consumption in compressor	Unexpected oil consumption in compressor
Valve packing leakage within acceptable limit	Valve packing leakage above acceptable limit
Administrative worker arrives late for work	Licensed operator arrives late for work
Worker discovers a formatting error in a procedure	Worker discovers a technical error in a procedure
Worker picks up wrong dosimetry badge, immediately realizes it and replaces it	Worker picks up wrong dosimetry badge and wears it into the work place
Shift operator performs walkdown but forgets to sign the walkdown checklist in the safety equipment room	Shift operator fails to perform walkdown in the safety equipment room
Job task takes longer than required (no consequence)	Job task in radiological area takes longer than required
Lighting breaker trips	Breaker for safety related system trips
Work order contains incorrect name of worker to perform the work	Work order contains incorrect piece of equipment to be worked on
Maintenance worker forgets tools required for performance of maintenance task	Maintenance worker performs maintenance with incorrect tools
Non-critical equipment runs to failure within acceptable period and with no consequence to the plant	Unexpected repeat failure of non-critical equipment — trend for preventive maintenance

The actual reporting level of events will depend on the organizational development/maturity (see Annexes V and VI), and on the management systems and processes that are in place. In a plant with a strong safety culture, the timely reporting of LLEs and NMs will be well established for conditions that meet thresholds similar to those described in Table 1.

Each NPP will need to develop its own threshold for reporting LLEs and NMs based on its current stage of organizational development/maturity. External benchmarking visits are an extremely useful tool for establishing industry norms and best practice, and these are well supported through organizations such as the IAEA, WANO, INPO and various reactor type owner groups.

4.2. OBSTACLES TO THE REPORTING OF LLEs AND NMs

Managers establish an environment where people (plant personnel and contractors) develop a feeling of responsibility for detecting component and system failures, and human errors. Nonetheless, people may not be willing to report LLEs and NMs for the following reasons:

— Reporting tools are unavailable (e.g. no access to forms or computers).
— Reporting tools are too cumbersome (e.g. complicated forms, lack of computer skills).
— Reports are not adequately reviewed or insufficient feedback is provided.
— Reporting is viewed as unnecessary because the person involved believes he or she can take care of the situation alone.
— There is a belief that the outcome of reporting will not change anything (i.e. no action will be taken, or the report will not be used).
— Fear of personal consequences.
— Reporting creates additional work.
— Human nature — reporting of individual mistakes can be embarrassing.
— Group interaction — reporting on others' mistakes may cause embarrassment or conflict between individuals or groups.

Many of these obstacles can be overcome by:

— Providing proper training on the use of tools for reporting LLEs and NMs;
— Providing feedback on LLE and NM results;
— Publicizing improvements that result from LLEs and NMs;
— Including the reporter in the development of actions based on his/her own suggestions;
— Using a quick and simple reporting format/style;

— Creating a well established ‘blame free’ or ‘just’ culture;
— Visible incentive programmes;
— Ensuring active management engagement and support, including reinforcement of expectations.

4.3. USER FRIENDLY SYSTEM FOR REPORTING OF LLEs AND NMs

In order to create a simple and effective process, and to comply with timeliness requirements, managers are to ensure that adequate tools for reporting are readily available. These may include paper based or intranet reporting forms, multiple communication channels with diverse support, email, and databases to store, retrieve and analyse LLE and NM information. Depending on the prevailing culture and organizational maturity, reporting channels may be open, confidential or anonymous in nature.

The best performing plants now capture in the order of several thousand events per reactor annually, and have recognized that capture and processing via paper based systems is too resource intensive. As a result, these plants have implemented fully electronic OE databases which permit easy input, coding and trend analysis of high volumes of LLE and NM data, as well as retrieval of historical data. The capital costs of such systems are outweighed by the benefits, as they can be managed with fewer human resources than paper based arrangements and result in significant safety and performance improvement as well as cost reduction. It is recognized that during the transition from a paper based system to a fully integrated OE system, many databases may need to be combined. However, there are many benefits from using a fully integrated database system, including: improved and simplified data management; more powerful trend analysis; additional inputs to management decision making; support for periodic safety reviews, probabilistic safety analysis and risk assessment; and support for regulatory reviews.

At an NPP in India, the reporting of LLEs and NMs jumped from a few hundred inputs to a few thousand per year for a twin unit station after the paper based reporting system was replaced with a web based reporting system (see Section II–4 of Annex II).

5. SCREENING ARRANGEMENTS

5.1. ESTABLISHMENT OF A CROSS-DISCIPLINARY SCREENING PROCESS OF EVENTS

Screening of LLE and NM information is undertaken to ensure that all significant safety relevant matters are considered. The best performing NPPs perform a prescreening of all reports via a corrective action programme (CAP) group in order to clarify and enhance reports, and to ensure that immediate actions are taken, if necessary. Subsequently, a daily screening meeting is held, which is chaired by a senior manager and supported by representatives from key functional areas (such as operations, maintenance, engineering, health and safety) to ensure that proper categorization and action assignment takes place. Best practice indicates that consistent membership at such screening meetings ensures consistency in the screening of reports and enables the detection of emerging trends that may indicate that an unsafe condition is developing.

Screening is used to establish priorities. A qualitative evaluation may also be used for this purpose. Plants typically use a priority hierarchy such as the following:

- *High priority.* Requires immediate attention. Safety or plant reliability is affected. May require root cause analysis.
- *Moderate priority.* Of lower significance than high priority, but requires resolution in a short time. Often requires apparent cause evaluation (less stringent than root cause analysis).
- *Routine priority.* A condition that has minimal effect on the safe and reliable operation of a plant or on personnel. The condition is sufficiently minor that apparent or root cause analysis is not required.
- *Low priority.* No further action required; entered into the database for trend analysis only.

LLEs and NMs usually fall into the last two categories and only require simple correction or inclusion in trend analysis; however, investigations may be initiated into special cases after screening. Some NPPs use risk matrices to determine the significance of reports. These risk assessments determine the priority of corrective actions; if appropriate, this will result in LLEs and NMs having as high a priority as some significant events (see Section II–5 of Annex II for examples of risk analysis matrices).

6. LLE AND NM CODING AND TREND ANALYSIS

Fundamental to the LLE and NM process is the effective analysis and correction of adverse conditions identified in LLE and NM trend analysis. It has been shown that the organizational or programmatic common causes of trends are the same as those that result in significant events. Trend and common cause analysis of LLEs and NMs allows an NPP to strike the correct balance between safety and production. As described earlier in this publication, significant events are costly in terms of losses in both production and company reputation. Figures 3–5 demonstrate the evolution of a less effective LLE and NM trend analysis process through to a fully effective process.

In Fig. 3, latent organizational weaknesses remain undetected, since the NPP is merely reacting to events without proactively identifying and correcting event precursors through trend analysis and analysis of LLEs and NMs. This results in the repeated occurrence of significant events. When these events occur, the NPP reacts to them and puts measures in place that improve safety. However, the NPP does not take a proactive approach to addressing the underlying or systemic causes.

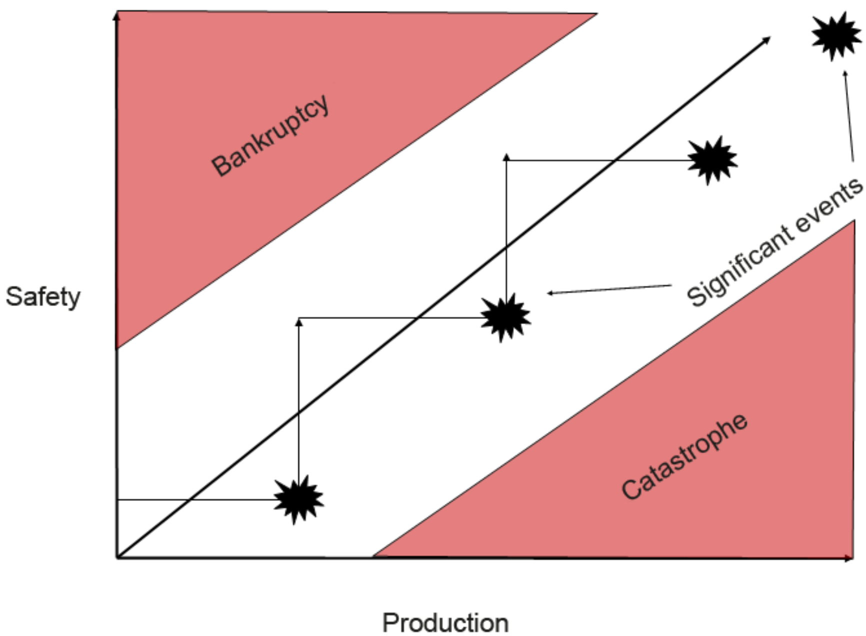

FIG. 3. LLE and NM process without LLE and NM reporting and trend analysis.

In Fig. 4, insufficient LLE and NM reporting and trend analysis is performed; therefore, significant latent organizational weaknesses remain undetected. The time between significant events is long enough that the significant organizational weaknesses are not exposed and corrected, resulting in a catastrophic event.

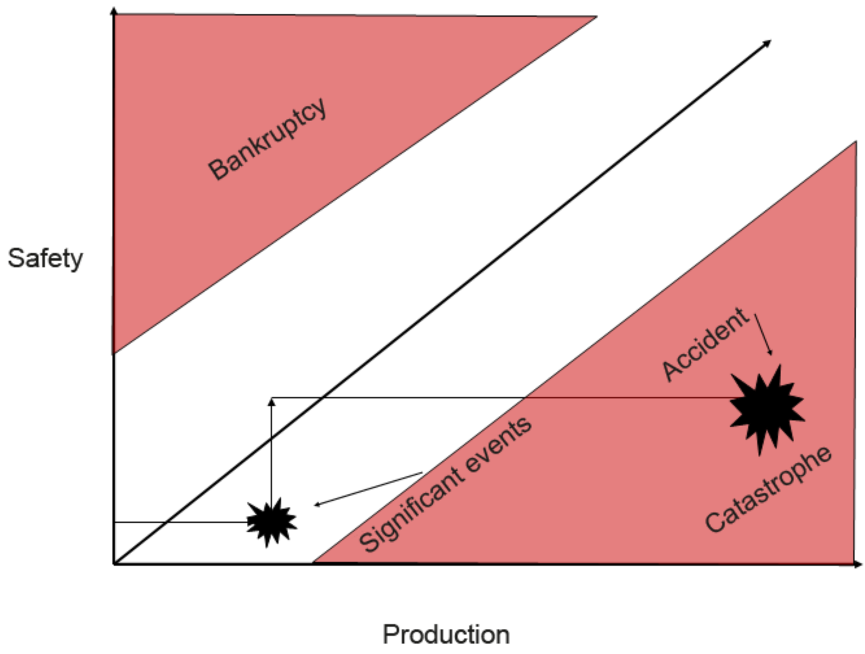

FIG. 4. LLE and NM process with insufficient LLE and NM reporting and trend analysis.

Figure 5 shows an optimal situation in which regular trend analysis and correction of LLEs and NMs identifies and corrects latent organizational weaknesses before they are revealed by a more significant event.

6.1. CODING OF EVENTS

All reports, independent of their severity and/or consequences, need to be coded and collected in the OE database in order to efficiently deal with the large amount of data generated by a LLE and NM process. Trend coding systems may be obtained by starting with standard coding systems such as the WANO event coding system or the IAEA's International Reporting System for Operating

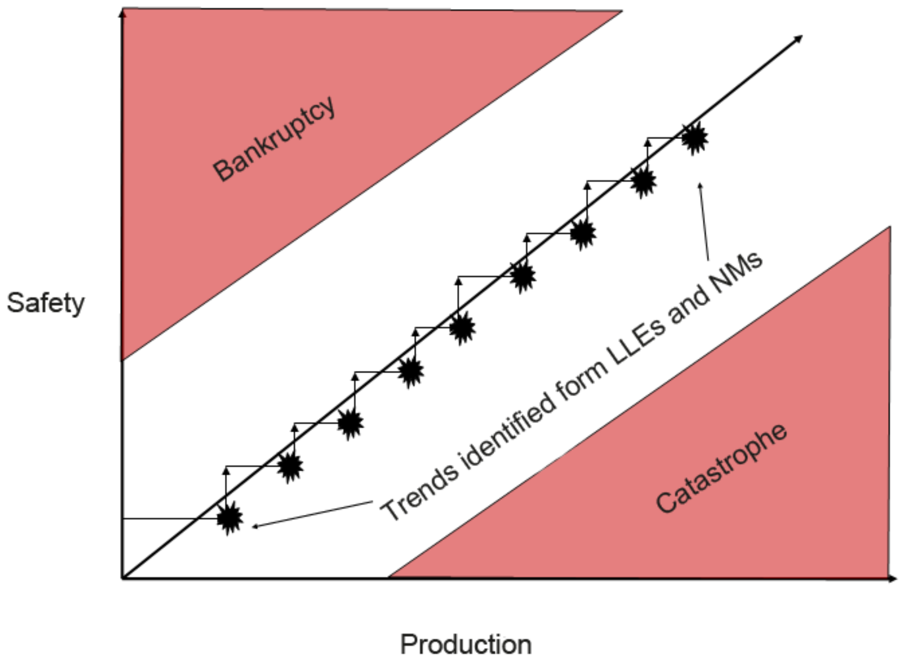

FIG. 5. LLE and NM process with regular trend analysis and correction of LLEs and NMs.

Experience (IRS) to attribute direct or apparent cause. Additionally, some commercially available examples of cause codes include: HPES process, TapRoot, MORT, and Performance Improvement International (PII), along with industry specific examples developed by other operators, available via information exchange programmes. However, experience has shown that these coding schemes do not always provide adequate levels of detail for trend analysis of non-consequential LLEs and NMs, and further tailoring for a specific NPP may be required.

As mentioned in Section 4.3, best practices suggest that computerized information systems be used to facilitate management of the large amounts of information generated by the LLE and NM process. Such systems can be adapted to enable finely structured searches for the information that is needed to detect trends, patterns and generic issues.

The coding of events plays an essential part in the effectiveness of the process, since it reduces event information to a few essential characteristics which are used for further analysis. Proper coding is the basis for a valuable set of data. In order to achieve this, simple coding schemes are used for LLEs and NMs. These include:

— Event codes: used in every report to categorize what happened or what nearly happened;
— Causal codes: used to categorize why an event happened (where possible or available);
— Key words: may be used to enhance text searching capabilities.

Note that for more complex reports, more than one event code may be utilized to further enable trend analysis capabilities. Also, free text searches are often used to further enable the identification and analysis of trends.

Ideally, coding schemes will enable effective trend analysis and analysis of generated reports. For example, too many trend codes associated with a relatively low total number of reports can delay the identification of important trends. Conversely, too few trend codes with a high total number of reports make analysis of meaningful trends too difficult.

Special attention has to be given to ensuring that events are coded consistently and that trend codes are collectively reviewed by a multidisciplinary group with consistent representation. Furthermore, before closing an event report, it is desirable to review trend codes and, when necessary, update them to reflect the further evaluation that was performed.

The best performing coding schemes are capable of transforming large amounts of data into useful information that supports decision making and reduces workload for staff at a low cost. Good database software enables efficient and effective coding and analysis of a lot of information. Software needs to be user friendly and easily available, and provide a wide range of features without the need for significant training.

6.2. TREND ANALYSIS

Trend analysis is a process based on the analysis of LLE and NM trends (precursors) used to identify degrading conditions that have not yet resulted in a significant event. LLEs or NMs form the majority of reports among total reported events at an NPP. Individually they may appear to be unimportant. However, as discussed in Section 5.1, a very small number of perceived LLEs and NMs may turn out to be of high or moderate priority following screening or further investigation. The majority will be of routine or low priority, which will be subjected to trend analysis. However, an accumulation of LLEs or NMs in the same area or with a similar pattern may indicate a weakness in a programme.

It is important to identify trends (improving, declining or stagnant) in plant performance and other areas that may not be apparent to the day-to-day observer. To this end, LLE and NM data are to be analysed periodically. It is important that an effective trend analysis process include management involvement and be proactive instead of reactive in nature.

Better performing plants routinely carry out an important independent quality check of trend analysis. It is important to monitor the generation of event reports by departments or sections in order to identify and ensure adequate engagement in the event reporting process by all sections. Inadequate engagement can result in undetected shortfalls or deterioration of performance.

6.3. IDENTIFICATION OF TRENDS

Ideally, identification of adverse trends will not be based simply on numerical values. For example, management may accept many insignificant lighting problems, but a small number of reactivity control issues can present a trend that needs to be addressed within a short time frame. Therefore, a key component of trend analysis has to be the significance of the events constituting the trend.

Trend reviews are meant to be cyclical and of sufficient frequency to identify emerging trends. These can be performed through data review meetings by station management or via the generation of adverse trend reports at a set frequency.

The data capture and coding process used must have a hierarchical structure to enable multi-level analysis by a trend evaluator. This helps trend evaluators to group reports into areas for monitoring and further evaluation.

The most basic trend process is the production of a simple histogram that counts the frequency of event reports in a certain area for a specified period of time. The process of determining priority for further investigation can then be decided by the techniques that are most appropriate to the organization. These include:

- Basic numerical histogram analysis;
- Above average value histogram analysis;
- Pareto analysis;
- Standard deviation analysis.

There are several types of trend that may indicate that further action is required. These include:

- Declining performance trend: a steady increase in the number of events over a period of time.

— Emerging trend: a trend that is just starting to appear at a frequency or significance level not yet at the acute level that may nonetheless require proactive correction.
— Acute trend: a large increase in the frequency of events over a short period of time.
— Watch list monitoring trend: improvement sought within a department or process for a previously identified deficiency that is not progressing at the desired rate.
— Unstable process trend: sporadic frequency of events over a long period of time.
— Negative engagement trend: absence of event report data for a department or process from which data were expected, revealing a lack of self-identification or reporting of issues.
— Cognitive trend: identification of a perceived trend by individuals or groups.

The management of each NPP will need to decide what degree of statistical boundaries is appropriate for its level of LLE and NM analysis; differing boundaries reflect the individual maturity levels of plants.

An example of a simplified trend process flow sheet is included in Annex XI.

6.4. EVALUATION OF IDENTIFIED ADVERSE TRENDS

As previously discussed, it has been determined that the causes of trends of LLEs and NMs are the same as those of more significant events. At the best performing plants where high numbers of event reports are generated, rather than trying to assign corrective actions to each LLE and NM, it is considered very important to perform careful analysis of the causes of trends that have been identified. To achieve this, the culture within the organization must accept that not all event reports will be corrected immediately and that it is acceptable to close some of these for trend analysis purposes. Failure to adopt this approach can lead to an overwhelming and debilitating number of corrective actions for an NPP.

When a trend has been selected for further investigation, it is documented and a methodical evaluation is initiated. This evaluation needs to identify causes of the trend. If common causes are identified, then appropriate corrective actions can be taken in order to eliminate the programmatic or organizational weakness.

At better performing plants, once a trend evaluation has been completed, an independent quality check by a responsible manager is performed prior to submission of the trend evaluation for approval and action by the station management team. An example of a trend evaluation check sheet from an NPP is included in Annex XII.

7. DISSEMINATION OF INFORMATION ON LLEs AND NMs

In order for staff to continue to be motivated to share and report LLEs and NMs, timely and effective dissemination and application of data is necessary. Some common methods used by NPPs to disseminate information include:

- Training activities;
- Just-in-time information;
- Pre-job briefings and work packages;
- Shift briefings;
- Safety meetings;
- Management and work control meetings;
- Plant information display screens;
- Station publications highlighting industry and facility OE information;
- Industry and station OE via electronic bulletin boards and email;
- OE notebooks;
- Utility web sites and databases;
- Information from and to a designer/vendor, if applicable.

After the LLE and NM process has been successful in reducing the number of significant events, dissemination of information is an essential tool to maintain staff alertness to potential risks.

Additionally, external organizations such as vendor groups, reactor type owners groups (e.g. CANDU Owners Group, Westinghouse Owners Group) and national and international organizations (e.g. INPO, WANO, Electrical Power Research Institute (EPRI)) exchange LLEs and NMs data, including steps taken to correct adverse conditions and trends, where appropriate.

It is important for managers to regularly assure plant personnel that their efforts to identify LLEs and NMs are worthwhile and valued. The engagement of staff can also be reviewed through anonymous surveys. Results from the LLE and NM process, together with staff survey results, are therefore fed back to those involved, as appropriate, and to personnel, who are expected to initiate reports.

Good practice concerning sharing of NM information with plant staff and contractors, identified during an OSART mission to the Mihama NPP in Japan, is included in Annex XIII.

8. MEASURING THE EFFECTIVENESS OF A LLE AND NM PROCESS

8.1. ESTABLISHMENT AND MAINTENANCE OF A SUITE OF PROCESS INDICATORS

The best performing plants establish and maintain a suite of LLE and NM indicators to monitor and manage the LLE and NM process. Such indicators are periodically assessed to pinpoint opportunities to adjust and improve individual and organizational performance.

Some examples of useful process indicators include:

- Reporting levels, by department;
- Percentage of self-identified issues (departments reporting versus not reporting their own issues);
- Ratio of internally to externally identified issues (externally identified issues include those raised by, e.g., regulators, peer reviews, OSART missions, external audits);
- Number of trend evaluations initiated;
- Trend evaluation quality;
- Ratio of number of trend evaluations targeted to those completed;
- Time required to complete trend evaluations;
- Ratio of LLEs and NMs to significant events;
- Ratio of self-revealing to self-identified events (proactive versus reactive);
- Ratio of LLEs and NMs related to human performance to those related to equipment;
- Number of corrective actions derived from trend analysis.

8.2. SELF-ASSESSMENT, BENCHMARKING AND PEER REVIEW

Self-assessment reviews assess the effectiveness of an OE programme as a whole and are to include as one element an assessment of the LLE and

NM process. To facilitate a self-assessment programme, indicators of process effectiveness are developed by the NPP. These may include those listed in Section 8.1.

External reviews (e.g. OSART, PROSPER, WANO/INPO peer reviews) determine whether a programme for operating experience feedback, including LLE and NM activities, meets internationally accepted standards and identifies areas for improvement. Such reviews normally relate the performance of the LLE and NM process to international standards and best practices and consider different approaches to implementation of the process.

In addition to the above methods, high performance organizations also take advantage of other improvement opportunities. Examples include but are not limited to:

- Benchmarking visits to better performing NPPs;
- Benchmarking of non-nuclear industries such as the petroleum, chemical, airline, aerospace, military, medical and health care industries;
- Continuous review of industry best practices;
- Remote benchmarking such as telephone, video link and Internet;
- Technical support missions from the IAEA, WANO, INPO, vendor groups;
- Participation in information exchange groups such as reactor type owner groups and EPRI.

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Annex I

EXTRACTS FROM THE OSART AND PROSPER GUIDELINES

The following extracts from the IAEA Operational Safety Review Team (OSART) and IAEA Peer Review of the Effectiveness of the Operational Safety Performance Experience (PROSPER) review guidelines provide examples of typical questions used by reviewers to assess LLE and NM process efficiency and effectiveness at an NPP:

- Does the scope of the OE programme include the reporting of LLE and NM events?
- Is LLE and NM reporting actively encouraged?
- Is the reporting threshold appropriately chosen to encourage the reporting of LLEs?
- Is the reporting process user friendly (ease of reporting, availability of forms/access to computers, access to results and feedback to staff)?
- Is there a declared policy of ‘blame free’/‘just’ reporting? What is the staff perception? Are actions considered to be punitive?
- Is there evidence in the plant of unreported deficiencies, event precursors or error likely situations (e.g. defective equipment, poor material conditions, poor or unsafe working practices, uncontrolled operators’ aids, lack of document control, operator logbook entries not captured in the LLE and NM process)?
- Does the event reporting database include LLEs and NMs?
- Does the event screening process include screening of LLEs and NMs?
- Are trend codes adequate to allow for proper coding of LLEs and NMs?
- Is trend analysis carried out on a regular basis, with the results of analysis reported to management?
- Are corrective actions identified through trend analysis and completed in a timely manner?
- Are effectiveness reviews performed for corrective actions from trend analysis, and have the identified trends actually been corrected?
- Does the trend analysis and evaluation process identify generic implications, precursors of declining performance and root causes of adverse trends?

These attributes can be used effectively to assist plant focus on self-assessment of the LLE and NM process.

Annex II

LLE AND NM PROCESS: EXAMPLES OF BEST PRACTICE

The examples contained in this annex are intended to provide insights into what some of the better performing utilities programmes cover within the LLE and NM environment. These examples are not intended to be prescriptive; rather, they provide potential benchmarking opportunities.

II–1. BRUCE POWER, CANADA

Brief description of NPP/utility

— Eight pressurized heavy water reactor CANDU units;
— Units 1 and 2, currently undergoing major refurbishment in a drained and defuelled condition;
— Bruce A plant: 4 × 750 MW(e);
— Bruce B plant: 4 × 850 MW(e);
— In-service dates for Bruce A units: 1976, 1977, 1978, 1979;
— In-service dates for Bruce B units: 1984, 1985, 1986, 1987.

OE organization

The OE, Corrective Action Programme (CAP) and Human Performance (HU) Sections are located within the Performance Improvement Department, which is in the Nuclear Oversight and Regulatory Affairs Division.

The CAP Section is responsible for coordination of screening and analysis of all internal event reports, including LLEs and NMs. Evaluations are conducted by subject matter experts and team leads (where teams are used) from line organizations, with CAP process mentors. Results of analysis and suggested corrective actions are approved by multidisciplinary teams of managers (management review meetings (MRMs) for apparent cause evaluations (ACEs), or corrective action review boards (CARBs) for root cause evaluations (RCEs)) and are then implemented. The completion of corrective actions to prevent recurrence (CAPRs), which are generated from RCEs only, is also reviewed by CARBs, in order to facilitate appropriate implementation and timeliness.

Management expectations

The station condition record (SCR) process is used to document adverse conditions, investigation results and corrective actions related to people, the plant, the environment and the process.

Management's expectations with regard to the reporting of NMs, LLEs, error likely situations, incidents, adverse conditions and events are as follows:

- Events, incidents and error likely situations are adequately documented.
- Cause(s) are determined.
- Appropriate corrective action(s) are implemented.
- Lessons learned are identified for communication to internal and external organizations.

An error likely situation is a behaviour, practice or condition that could result, but has not yet resulted, in a loss.

Loss is defined as: harm to people; harm to reputation; damage to plant or property; interrupted productivity; regulatory violation and activity or condition reportable to the regulatory body; harm to the environment; radiological exposure; or reduced margin of reactor safety. An incident is an event that could or does result in unintended harm or damage.

An adverse condition is an undesirable situation, state or circumstance related to people, the plant, the environment or the process, or an event, an incident or an error likely situation that has resulted in loss, or that has the potential to result in loss.

An event is a consequence exceeding some criteria of significance, involving an unwanted change in either the health or well-being of employees, the environment or safety margins, or in the ability of the plant to perform its design functions.

Overview of the programme

Purpose

The SCR process is used to document adverse conditions, investigation results and corrective actions related to people, the plant, the environment and the process. A consistent reporting and evaluation process for identified adverse conditions at Bruce Power is required, to minimize losses related to people, the plant, the environment and the process by ensuring the following:

— Events, incidents and error likely situations are adequately documented.
— Cause(s) are determined.
— Appropriate corrective action(s) are implemented.
— Lessons learned are identified for communication to internal and external organizations.

Exceptions

Adverse conditions related to confidential employee relations are excluded. For security related adverse conditions for which a degree of confidentiality is required, the intent of the process is to be followed, but the event, its subsequent investigation and corrective actions are made available for staff review on a need to know basis only.

Levels of investigation

The following levels of investigation are available. The line manager recommends an appropriate level of investigation (see Table II–1); the recommendations are then reviewed and confirmed by corrective action programme coordinators (CAPCOs) and MRMs.

Root cause investigation. An extensive root cause analysis is to be completed by a team of individuals or by an individual no more than 28–30 days from the event date in accordance with BP-PROC-00518, Root Cause Investigation. The responsible manager is an executive vice president, vice president or department manager. Resolution category A will be assigned.

Equipment root cause investigation. An extensive root cause analysis is to be completed by a team of individuals or by an individual no more than 28–30 days from the event date in accordance with BP-PROC-00518, Root Cause Investigation. The responsible manager is an executive vice president, vice president or department manager. Resolution category A will be assigned.

Apparent cause evaluation. Requires an investigation into the apparent cause of the adverse condition in accordance with BP-PROC-00519, Apparent Cause Evaluation. The investigation is usually conducted by a single investigator within 35 days of the date the MRM assigns the evaluation. The responsible manager is a department manager or section manager. Resolution category B will be assigned.

Equipment apparent cause evaluation. Requires investigation into the common causes of an adverse trend in accordance with BP-PROC-00644, Trend Evaluation. The investigation is usually conducted by a single investigator within 35 days of the date the MRM assigns the evaluation. The

TABLE II–1. INVESTIGATION LEVELS FOR EVENTS

Resolution category	Description	Significance level	Description
A	Requires a root cause analysis or equipment root cause analysis to determine CAP. Usually involves a team for a week or longer.	1	A highly significant incident/event or substandard condition that causes a major reduction in the margin of safety to the public or to station personnel and/or which has a major impact on the environment or on production or on other business deliverables.
B	Requires apparent cause evaluation or equipment apparent cause evaluation and/or any corrective actions outstanding.	2	A significant incident/event or substandard condition that causes some reduction in the margin of safety to the public or to station personnel and/or which has some impact on the environment or production or on other business deliverables.
C	Trend evaluation.	3	An incident or substandard condition which is not significant by itself, but which has the potential to be more significant or which may be the precursor to a more significant event.
D	Corrective actions assigned.	4	A minor incident or condition adverse to quality which will help to identify, by means of a trend analysis, those areas that need more attention.
E	Cause is known and all corrective actions have been taken (or MRM decides no action is required).	5	Not significant, e.g. 'NE' resolution category.
		If the assigned resolution category or significance level is different from recommendations of the front line manager, a rationale for the change is to be provided.	

responsible manager is a department manager or section manager. Resolution category C will be assigned.

Trend evaluation. Requires an investigation into the common causes of an adverse trend in accordance with procedure BP-PROC-00644, Trend Evaluation. The investigation is usually conducted by a single investigator within 35 days of the date the MRM assigns an evaluation. The responsible manager is a department manager or section manager. Resolution category C will be assigned.

Corrective actions assigned. Requires specific defined action to correct an adverse condition. If 'corrective actions assigned' is the recommended level of investigation, the front line manager needs to provide the following information: a description of the corrective action required, the due date for completion, the alert group the action ought to be assigned to, and the name of the person who has accepted the action. Resolution category D will be assigned.

No further action required. This level of investigation is normally only recommended if the adverse condition has been corrected and documented in the SCR in the 'immediate actions taken' field, or of the adverse condition is being documented to provide data in support of an adverse trend identification and/or evaluation. Resolution category E will be assigned.

Daily condition report screening meeting

The daily condition report screening meeting is a daily meeting of CAPCOs, with a rotating chairperson. The meeting serves as a collegial review of all prescreened SCRs prior to a station MRM. CAPCOs perform all prescreening functions including: initial trend code assignment, significance level validation and recommended investigation level/type/organization. A representative of the line organizations (the line CAPCO or backup supplied by the line) is required to attend each screening meeting and to fulfil CAPCO duties on a daily basis (as per procedure SEC-CAPP-00001, Corrective Action Programme Coordinator). An SCR is raised to document any failure to meet this requirement.

If the CAPCOs do not have enough information to resolve the SCR at the initial screening meeting, the issue can be brought back to the next day's screening meeting. Of SCRs screened at the initial screening meeting, 90% concern acceptable performance of the CAPCOs and the line organizations providing them with the information required (10% are 'bring backs'). In no case can an SCR be brought back more than three times.

Overview of OE resources

OE and CAP consist of 18 people — one department manager, four programme administrators, three external operating expenditures (OPEX) coordinators, seven investigators/coordinators, one administrative assistant and two business support representatives. These people are functionally assigned duties for the Bruce A station, Bruce B station and the corporate office (this was in preparation for 'fleet model' Performance Improvement Department staff deployment in 2010).

Key focus areas

Past and present

- Upgrade of the CAP software program from the existing condition reporting application to Passport-V10, and Esuite (a web based, user friendly interface).
- The HU Section is new, with three full time HU managers (Bruce A, Bruce B, and corporate).
- Hiring of several of the 18 department staff took place in preparation for deployment to 'fleet model' organization with most staff assigned to Bruce A and Bruce B stations. Staff will continue to report to the performance indicator (PI) Department manager but will more closely support the stations in their day-to-day operations.

Future

The Bruce Units 1 and 2 restart project lessons learned/OE process is challenging, because construction organizations are not accustomed to operating within a nuclear business culture of openness with regard to the reporting of LLEs and NMs.

Preparations for the 2011 business plan included an external OPEX software program for handling and processing external OPEX (incoming) and for reporting of internal OPEX to the industry (outgoing). An OPEX handling software upgrade, including significant process efficiencies, is targeted.

Successes

- — The reporting level for LLEs and NMs has increased from approximately 600 reports per unit eight years ago to approximately 3500 reports per unit in 2009.
- — There has been an increase in the identification of trend evaluations on identified adverse trends at a significance level of 3 or above. The company recently implemented an upgraded trend evaluation process that now turns a number of related SCRs into organizational and/or programmatic causes which are evaluated via an ACE or RCE, depending on the significance of the adverse trend.
- — Conditions reportable to the Canadian regulator (Regulatory Standard S-99) have steadily declined as the reporting of issues has increased.
- — Conventional safety improvements have been seen, with over 18 million person-hours worked on the six operating units without a 'lost time injury', (the last one occurred in June 2007). The use of an improved CAP, including a significant increase in the reporting of LLEs and NMs (precursor issues), followed by trend evaluations, has been instrumental in achieving this significant improvement. The benefits to the company, including reduced loss of morale, reduced loss of production and reduced accident handling costs, are significant.

Challenges

- — How to manage human performance improvement while a rapidly ageing workforce is replaced with younger workers who are new to the nuclear industry, including new supervisors and managers.
- — How to extend the success in conventional safety management to other key areas of business performance.

Figure II–1 plots safety events, safety precursors and total SCR generation at the site from 2006 through 2009. Significant safety events have declined as SCR generation and subsequent low level precursor identification have improved.

Figure II–2 plots conditions reportable to the Canadian regulator (Regulatory Standard S-99), which declined steadily as the reporting of issues increased from 1 January 2005 to 31 December 2009. As SCR generation and subsequent low level precursor identification have improved and have been dealt with, reportable S-99 events have declined.

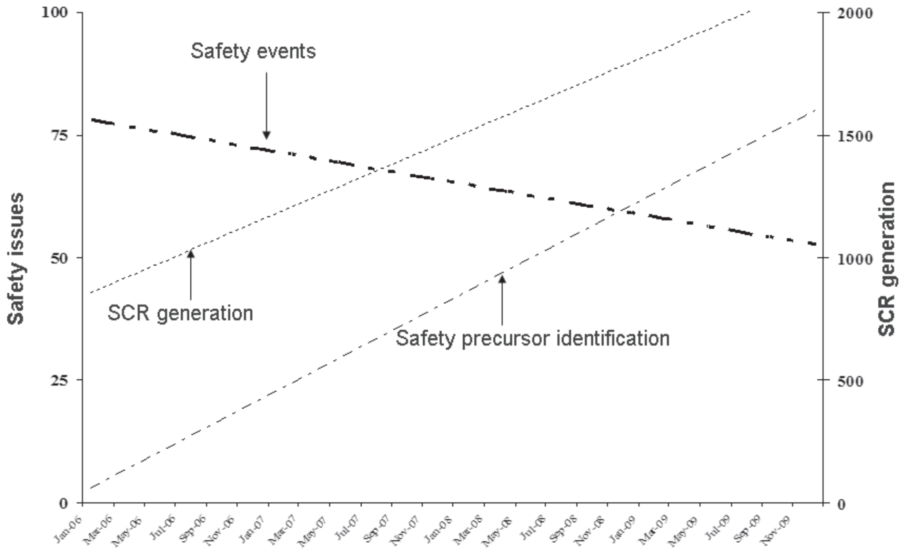

FIG. II–1. Bruce Power: safety events, safety precursors and total SCR generation, 2006–2009.

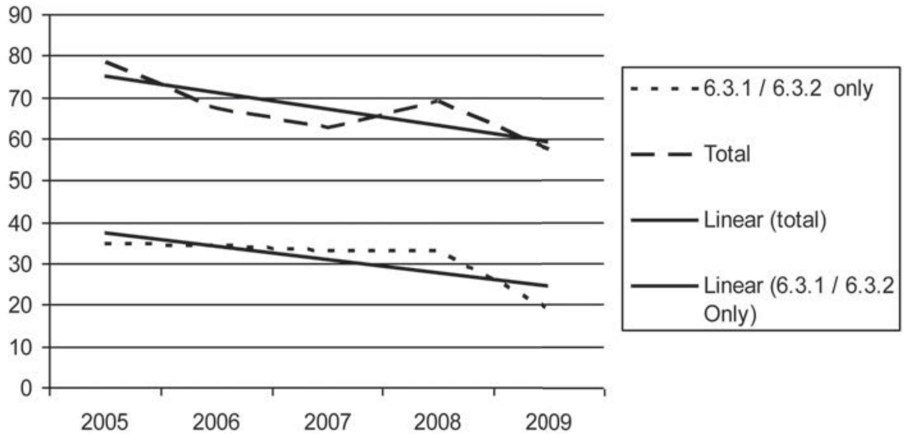

FIG. II–2. Bruce Power S-99 report trends per operating unit, 2006–2009.

II–2. ENTERGY NUCLEAR, USA

Brief description of NPP/utility

Entergy owns ten nuclear stations with 12 plants. These plants are as follows:

- Grand Gulf (boiling water reactor (BWR)), 1 × 1210 MW(e);
- River Bend (BWR), 1 × 996 MW(e);
- Waterford-3 (pressurized water reactor (PWR)), 1 × 1178 MW(e);
- Arkansas Nuclear One (PWR), 2 × 967 MW(e);
- Indian Point (PWR), 2 × 1033 MW(e);
- James A. Fitzpatrick (BWR), 1 × 850 MW(e);
- Pilgrim (BWR), 1 × 690 MW(e);
- Palisades (PWR), 1 × 798 MW(e);
- Vermont Yankee (BWR), 1 × 626 MW(e);
- Cooper (BWR), 1 × 801 MW(e).

OE organization

The Corrective Action and Assessment (CA&A) Department at each of the sites generally consists of full time staff, including a department manager, administrative assistant, corrective action specialist, cause analysis specialist and OE coordinator. The CA&A Department is responsible for overseeing the administration of the corrective action programme (CAP), which tracks all conditions and actions that result from internal inspections, evaluations and assessments, including LLEs and NMs, as well as the results of inspections, evaluations and assessments conducted by organizations such as INPO, the US Nuclear Regulatory Commission (NRC), the US Occupational Safety and Health Administration (OSHA) and other, similar external organizations. Additional support is provided by the corporate CA&A Department. The OE coordinator at each site coordinates internal and external OE for the site to ensure that internal OE is provided to site departments and to other sites in the fleet for consideration of applicability. In addition, external OE is evaluated for site and fleet applicability. The CA&A Department coordinates the reporting and addressing of conditions reported in the Paperless Condition Reporting System (PCRS) for the site. This includes all condition levels as described below (including LLEs and NMs). Strong ownership of specific conditions by the appropriate department is expected and demonstrated at each site.

Management expectations

Company procedures, aligned for all plants in the fleet, provide for the reporting of adverse conditions and conditions adverse to quality, as well as any condition that may challenge the safe operation of a plant. Workers are encouraged and expected to report all conditions at any level, and the programme is designed to screen conditions to ensure the appropriate response level.

Overview of the programme

The following is a very general overview, intended to provide basic insights into applicable portions of the process. LLEs and NMs are captured via the CAP in the PCRS. Any worker can initiate a condition report (CR) at any level. Each day, a condition review group (CRG), consisting of site management personnel from each of the major site departments, chaired by the General Manager of Operations (GMPO/plant manager), screens the CRs initiated on the previous day. Condition reports are screened in a manner similar to that described in Section 5 of this publication, as Level A, B, C or D, with A being the most significant and D the least. LLEs and NMs account for the majority of the conditions identified, and are normally screened as Level C or D, but may also be screened as Level B if the CRG determines that an apparent cause evaluation (ACE) is warranted. LLEs and NMs will generally not rise to Level A, which comprises more significant conditions requiring a root cause analysis (RCA) to address the condition. ACEs and RCAs are required to be completed within 30 days, unless there is a compelling reason to allow an extension of this time frame, to ensure the timely determination of causes and implementation of corrective actions. Once completed, ACEs and RCAs are presented to a corrective action review board (CARB) for final approval prior to issuance. LLEs and NMs are investigated to the extent necessary to address and correct an identified condition, or in many cases are closed for trend analysis within the CAP. Monthly and quarterly trend reports are generated to identify trends from the PCRS, with the majority of the data resulting from LLE and NM conditions. Various other forums, such as department monthly reviews and Human Performance Review Board (HURB) meetings are employed to review data and determine actions necessary to continually improve performance.

In general, plants initiate approximately the following number of condition reports per reactor annually: Level A — 5–10; Level B — 100–300; Level C — 1000–2500; Level D — 2000–4500. The spread in reporting levels can be attributed to different levels of performance across the fleet.

Overview of OE resources

As indicated above, the CA&A Department at each of the stations consists, in general, of a department manager, administrative assistant, corrective action specialist, cause analysis specialist and OE coordinator. In addition, departments assign department performance improvement coordinators (DPICs) to coordinate corrective actions at any level within the department. DPICs are line organization staff members generally assigned this responsibility as a collateral duty.

Key focus areas

Past

The CAP was developed many years ago and has been continually developed and improved over time. Experience gained on the job, through information exchanges, via benchmarking, and by participation in internal and external assessments shows that initial implementation of a CAP is sometimes difficult. In the early implementation phases (20 or more years ago), staff sometimes resisted the change driven by the new programme. However, a strong commitment and belief in the programme by senior management has resulted in workers taking full advantage of the process and in significant performance improvement over time.

Present

The CAP, including the OE programme, is periodically assessed and evaluated by various mechanisms that include, but are not limited to:

- — Department and plant self-assessments.
- — WANO/INPO evaluations.
- — Regulatory inspections or problem identification and resolution effectiveness.
- — Nuclear insurers.
- — Benchmarking of high performing external organizations.
- — Particpation in industry information exchange workshops and conferences.
- — Monitoring of performance indicators such as:
  - • Number of Category A–D CRs initiated;
  - • Average age of CRs and corrective actions;
  - • Quality grading of cause evaluations;
  - • Average age of cause evaluations;
  - • Number of cause evaluations requiring more than 30 days;

- Number of overdue corrective actions;
- Number and rate of industrial accidents, LLEs and NMs related to non-consequential human performance errors (NCEs), consequential errors, human performance events.

Future

Work is being done at Entergy Nuclear to gain better results from the data tracked for NCEs, which equate to LLEs and NMs, by developing a performance indicator that is intended to track self-identified versus externally identified NCEs. The aim is to encourage more self-reporting of NCEs, with increased data and a greater opportunity to learn from LLEs and NMs, resulting in fewer consequential errors and events. It is recognized that higher level conditions are prevented by learning from lower level conditions, and thus the focus is on learning from LLEs and NMs.

Successes

In the early stages of programme implementation, consequential error rates decreased from 3.4 to approximately .07 errors/10 000 work hours in an 18 month period. A direct contributor to this success was the focus on learning from LLEs and NMs to prevent errors and accidents of greater consequence.

Below are additional examples of improved performance due to tracking and trend analysis of LLEs and NMs:

— Trend analysis of low level industrial safety incidents at one plant led to a team evaluation of the causes of and contributors to commonalities and to the development of actions to improve performance. As a result, a 44% reduction in the number of industrial safety incidents was achieved at that plant in a six month period.
— Trend analysis of low level industrial safety incidents for a specific fleet department led to a team evaluation of the causes of and contributors to commonalities and developing actions to improve performance. As a result, a 33% reduction in the number of industrial safety incidents was achieved within that department in a six month period.
— Trend analysis of low level material handling errors resulted in a team evaluation of the causes of and contributors to commonalities and to the development of actions to improve performance. As a result, no significant material handling incidents occurred within the fleet of 12 plants in the subsequent six month period.

Challenges

The number of low level and NM tagging incidents is not acceptable. However, recent examination of the situation has resulted in the formation of a team to review LLE and NM data associated with tagging and has identified common contributors and corrective actions to prevent further occurrences. The identified actions are in the process of being implemented with expected performance improvements.

Good practices to share

The programme is very robust with some basic practices for any developing utility to consider emulating. The following are examples of good practices to share:

- A strong nuclear safety culture with well trained staff willing to report incidents at every level;
- A significant focus on industrial safety, human performance and continuous performance improvement;
- A strong commitment by senior management to the CAP, including the use of OE and LLE and NM data to prevent future incidents;
- Full time staff administering the CAP, which includes the OE and the LLE and NM processes;
- Well trained cause evaluators and a strong commitment to providing resources to complete high quality cause evaluations;
- Encouragement of reporting at every level;
- The possibility for any worker to issue a CR;
- High volumes of corrective action data;
- Continuous monitoring of the programme by CRG, CARB, HURB, department management, etc.;
- Well developed and implemented corrective action, human performance and industrial safety performance indicators;
- Information sharing through the OE programme, both internally and with external organizations;
- A robust OE dissemination and application process;
- A defined and well implemented self-assessment and benchmarking process overseen by the Self-Assessment Review Board (SARB), chaired by the site vice president;
- Expectation of and commitment to timely implementation of corrective actions.

One particularly strong practice has been the implementation of a HURB. This process permits the periodic presentation of LLE and NM related human performance data to a senior management team. This results in a strong focus on continuous human performance improvement and challenges issued by the HURB to strengthen actions by individual departments.

II–3. EXELON NUCLEAR, USA

Brief description of NPP/utility

Exelon owns 10 nuclear stations with 17 reactors located in the Midwest and on the East Coast of the USA, making Exelon the largest nuclear utility in the USA and third largest in the world. Reactor types include Westinghouse PWRs and General Electric BWRs. Seven of the stations consist of two unit sites, and three of the stations have one unit. These plants are as follows:

- Braidwood (PWR), 2 × 1250 MW(e);
- Byron (PWR), 2 × 1250 MW(e);
- Clinton (BWR), 1 × 1150 MW(e);
- Dresden (BWR), 2 × 918 MW(e) (uprated);
- LaSalle County (BWR), 2 × 1150 MW(e);
- Limerick (BWR), 2 × 1150 MW(e);
- Oyster Creek (BWR), 1 × 670 MW(e);
- Peach Bottom (BWR) 2 × 1150 MW(e);
- Quad Cities (BWR), 2 × 960 MW(e) (uprated);
- Three Mile Island (PWR), 1 × 1250 MW(e).

The two unit stations employ about 650 full time workers each, and the single unit stations employ about 450 workers each. During significant outages staff typically doubles, with a contracted work force used for most of the reactor and turbine/generator or large project work.

OE organization

Exelon has a relatively small centralized OE organization at both the corporate office and at each NPP. There are five individuals working in the corporate office. Their primary duties include governance and oversight of the corrective action programme (CAP) and OE programmes for all of Exelon. Three individuals at each station provide local governance and oversight at the station level. Line organizations at the stations and within the corporate office perform daily CAP functions, including screening, trend analysis and evaluation of condition reports.

Management expectations

Within Exelon Nuclear, there are clear management expectations that all deficiencies and equipment failures will be documented within the CAP. This expectation specifically includes not only consequential deficiencies but also NMs and LLEs. These low level issues feed into a robust trend analysis process that is recognized by senior leadership as important to the success of Exelon. In order to reinforce the reporting of LLEs, assessments and audits, as well as metrics, measure the amount of reporting to ensure proper engagement in the programme. The nuclear oversight organization performs a comprehensive CAP audit every two years across the nuclear fleet to ensure that the CAP is being utilized from a regulatory compliance perspective as well as adding maximum value to the company. In addition, the NRC regularly performs a problem identification and resolution audit of each station’s CAP to ensure that regulatory compliance has been met.

Overview of the programme

Exelon’s CAP includes both equipment failure screening and processing as well as organizational issues. Issue reports (IRs) capture the initial deficiency. No immediate supervisor review of each IR is required unless the originator of the issue requests a supervisor review. Once initiated, the originator of the issue has the option to process IRs through the normal screening process or to expedite screening through the Operations Department for high priority issues. However, all IRs are screened by an Operations individual during a committee review of IRs within one business day to ensure that all operability issues are identified.

Once initiated, the IRs (which include both equipment and organizational issues) are reviewed by a committee of individuals called the Station Ownership Committee (SOC). If the SOC cannot determine the severity of an issue or the actions to be taken, then a supervisor review of the IR in question will be required. The SOC screens IRs each business day; the following individuals must be present: a licensed senior reactor operator and individuals from regulatory affairs, maintenance, engineering, work control, work package planning, the rapid maintenance team, radiation protection and chemistry. Work requests for equipment failures are generated from this meeting and are given an initial rating according to severity and priority. Organizational issues are also given a severity rating, and corrective actions are proposed based on the originator’s information and recommendations. It is important to note that the members of the SOC are experienced within their discipline to ensure that adequate representation is achieved during screening. Guidance for assignment of issue severity and priority is undertaken in accordance with procedural examples for consistency.

Once all information has been gathered and proposed actions have been assigned to an IR, the IRs are reviewed by the Management Review Committee (MRC). This committee consists of senior managers, who review all of the IRs that have been generated, including severity and actions or evaluations assigned. The ultimate responsibility for CAP implementation resides with this committee and not with programme administrators. This is how line ownership of a CAP is achieved.

In 2010, Exelon generated 95 849 IRs within the entire company, with 3053 of these generated at the corporate office and the rest at the ten nuclear stations. Significance is measured by number at Exelon, with the lowest number being the most significant. Level 5 issues are typically enhancements. The following numbers are the breakdown of IRs generated in 2010 by significance level: Level 1 — 5; Level 2 — 74; Level 3 — 1993; Level 4 — 86 744; Level 5 — 7033.

Typically, LLEs fall into the Level 4 and NMs into the Level 3 categories of significance.

Key focus areas

Past

Low level trend analysis of issues and evaluation of these trends has proved to be one of the most successful vehicles at Exelon for driving performance improvement. As there is a very low reporting threshold, there are many opportunities to expose low level trends. However, CAP metrics are utilized to ensure that the right level of engagement is also monitored so that low level trends are not missed due to lack of data.

Present

The most recent focus area within the company is equipment reliability. Exelon utilizes an enhanced version of the INPO AP-913 model for equipment reliability causal determination. This model, in conjunction with the careful identification of operational critical systems and components, provides the right focus on equipment reliability trend analysis to ensure that the majority of effort is expended on issues that can impact nuclear safety and generation.

Future

Equipment reliability will continue to be the focus for the foreseeable future, although many of the causes of equipment reliability issues are rooted in organizational and programmatic issues, such that when the extent of the cause is determined, the extent of the condition reaches other areas within various organizations, such as human performance programmes.

Successes

Annex IX provides examples where trend analysis of LLEs and NMs has had a positive impact within Exelon.

Challenges

The biggest challenge to the success of the CAP at Exelon is continued engagement of the work force in using the programme to document deficiencies and events. Although a significant number of IRs are generated at Exelon, diversification of individuals generating the issues offers many opportunities for further improvements in low level trend analysis of events, as trends cannot be developed unless IRs are being generated to document those issues.

Good practices to share

The common generation of equipment reliability issues along with the storage of the condition reports in one computer software program ensures maximum opportunities for equipment failure trend analysis. This provides valuable input into low level trend analysis and evaluation of critical component failures. This is one of the biggest competitive advantages that Exelon has realized from the CAP, as this process is comprehensive from the documentation of an actual equipment failure through to the evaluation and resolution of the issues behind such a failure.

II–4. NUCLEAR POWER CORPORATION OF INDIA LIMITED

The Nuclear Power Corporation of India Limited (NPCIL) operates around 20 nuclear power plants all over India, most of which are PHWRs:

- TAPS 1 and 2 (BWR), 2 × 160 MW(e);
- RAPS 1 (PHWR), 1 × 100 MW(e);

— RAPS 2 (PHWR), 1 × 200 MW(e);
— RAPS 3 and 4 (PHWR), 2 × 220 MW(e);
— RAPS 5 and 6 (PHWR), 2 × 220 MW(e);
— MAPS 1 and 2 (PHWR), 2 × 220 MW(e);
— NAPS 1 and 2 (PHWR), 2 × 220 MW(e);
— KAPS 1 and 2 (PHWR), 2 × 220 MW(e);
— Kaiga 1 and 2 (PHWR), 2 × 220 MW(e);
— Kaiga 3 and 4 (PHWR), 2 × 220 MW(e);
— TAPS 3 and 4 (PHWR), 2 × 540 MW(e).

Management expectations

OE is a valuable source of information for learning and for improving the safety and reliability of NPPs. One of the objectives of operating experience feedback is to ensure that no safety related events remain undetected and that corrective actions are taken to prevent the recurrence of events by improving design, modifying procedures and improving station practices. Since events are indicators of weakness or failure of the defence in depth barrier, proper reporting and investigation of events is an important element of operating experience feedback. For several years, OE has relied on events and significant events analysis to obtain critical information to feed into the organizational learning loop. However, the operating performance of NPCIL's plants has improved considerably over the past few years, and thus the number of reportable events in NPPs has also come down. With a reduced number of events, latent shortcomings in work practices or plant conditions may remain undetected. Since less significant problems are not reported, their root causes may remain unaddressed. The cumulative effect of these less significant events could be a slow decline in the safety performance of NPPs. Experience has shown that a relationship exists between non-consequential events and significant events. Most of the time, both share common causes that may lead to serious events. An organization has a large potential to learn through them.

Thus, there is a need to initiate reporting and analysis of LLEs. Such events have the potential to be instructive if they are reported and investigated in a timely and systematic manner. This is particularly important, as these events usually present a great variety and volume of information for learning. The idea is to detect and correct minor weaknesses early on so that they cannot develop into more serious conditions. Individually these events may appear to be unimportant, but when aggregated with other LLEs, they can reveal features of common patterns, trends and recurrent information which may be significant for further enhancing plant safety. An effective LLE reporting system can provide plant staff and management with information that can be used for self-assessment input.

Overview of the programme

LLEs include all deficiency reports (DRs), except those related to preventive maintenance or condition monitoring and those raised during biennial shutdown. LLEs may cover deficiencies related to housekeeping, job observations, audits, corporate reviews, station internal reviews and material condition. NMs are also to be reported within a LLE reporting system.

To streamline the process of reporting LLEs, a standard format was prepared and made available on the web based intranet for direct use by all individuals at each plant. If a person identifies a LLE, he or she is encouraged to fill out the LLE report provided on the web page. Each departmental LLE coordinator reviews the LLE reports related to his or her department on a daily basis.

After rectification of a deficiency, an engineer fills out the information on the LLE category and subcategory, depending on the nature of the defect and corrective action, taken from the standard drop-down list. The departmental LLE coordinator reviews the data for correctness.

A station level committee meets at least once a month to review all LLEs reported during that month. The salient points of the review are presented at one of the daily station meetings by a planning engineer on a monthly basis. The responsibilities of departmental LLE coordinators include compilation of information on LLEs in their department, as well as trend analysis, and analysis and submission of results to the station LLE coordination committee.

Trend analysis

After the World Association of Nuclear Operators (WANO) technical support mission on LLEs and NMs, NPCIL issued a revised policy publication on reporting of LLEs and NMs and a decision was made to change from a paper based reporting system to a web based reporting system. Since then, reporting has increased from a few hundred to a few thousand entries per year per twin unit station. LLEs and NMs reported for Rajasthan Atomic Power Stations (RAPS) 3 and 4 for 2009 are provided in Fig. II–3 under different categories.

Key focus areas

Past

A LLE programme was initiated in 2005. Initially, LLE reporting was being done on paper in a prescribed format. The coverage area and LLE reporting were

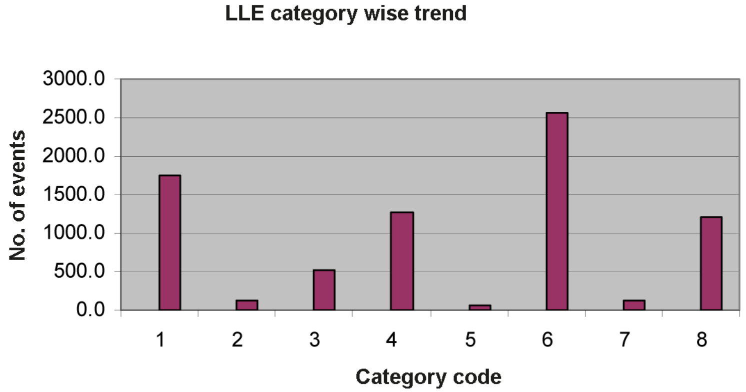

FIG. II–3. Total number of LLEs reported at RAPS 3 and 4 during 2009 according to category. The category codes are as follows: 1.0 — error reduction technique; 2.0 — radiation protection; 3.0 — industrial/fire safety; 4.0 — work practices; 5.0 — repetitive jobs; 6.0 — low level maintenance works; 7.0 — environmental conditions; 8.0 — equipment performance.

very low. After the WANO technical support mission in 2007, the organization's policy on the reporting of LLEs and NMs was revised.

Present

- Since January 2009, LLE reporting has been computerized. The coverage area has increased significantly.
- Initially, the data received were absurd, as the defined codes were inadequate and thus led to improper codification by users.
- Training and refresher training courses were provided to users on the proper categorization of LLE codes.
- More codes were defined to cater to requirements.
- A periodic review of the programme is being undertaken.

Future

To create awareness, the station training centre has been asked to periodically conduct seminars/training courses on LLEs. The LLE and NM process has been made a part of training courses by including a chapter or 30 minute session on LLEs within the following existing training programmes:

- Initial training;
- Refresher training;
- Training on industrial safety and emergency preparedness.

Examples of success

After effective implementation of a LLE and NM management process, a number of emerging trends were identified to initiate corrective actions. For example, one of the emerging trends identified in 2009 was loose connections/contacts. It was categorized under category 6.0 ‘low level maintenance works’, subcategory 6.7 ‘deficiencies in JBs/panels and indicator lamp not glowing, etc.’ Corrective actions were initiated and the trend started declining in the first quarter of 2010, as indicated in Figs II–4 and II–5.

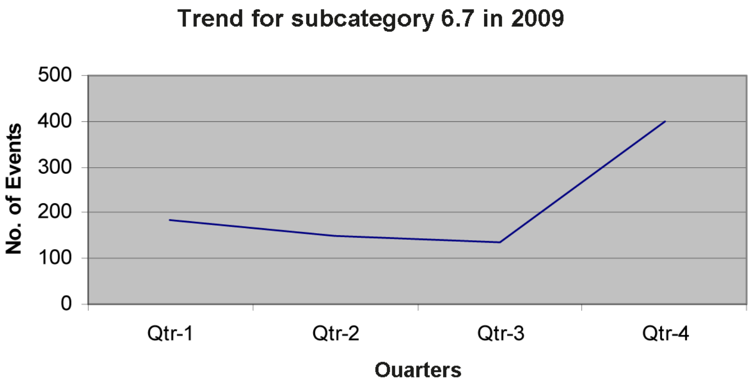

FIG. II–4. Success stories: Trend for subcategory 6.7 (deficiencies in JBs/panels, indicator lamp not glowing, etc.) in 2009 (RAPS 3 and 4).

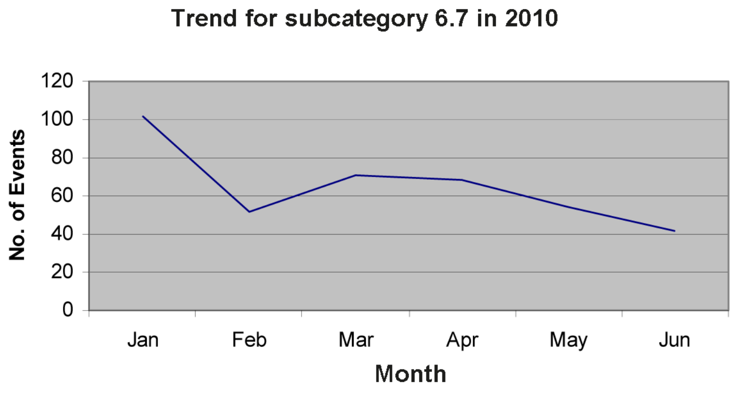

FIG. II–5. Success stories: Reversal of trend for subcategory 6.7 (deficiencies in JBs/panels, indicator lamp not glowing, etc.) starting in the first quarter of 2010 (RAPS 3 and 4).

Challenges

The events being collected in the LLE and NM process belong primarily to the area of maintenance, including equipment performance. There is still a need to capture events in the area of human performance in order to prevent events on account of human errors.

II–5. MOCHOVCE NPP, SLOVAK REPUBLIC

Brief description of NPP/utility

— Mochovce NPP (water cooled, water moderated power reactor (WWER)), 2 × 440 MW(e);
— Start of operation: 1998.

OE organization

OE programme implementation is coordinated by the OE section, located within the Safety Division. The OE section consists of four people — a leader, two root cause investigators and a trend analyst. Approximately 70% of their effort is spent on LLEs and NMs. Other departments provide human resources as needed to support effective implementation of the OE programme. The description below reflects the status prior to the implementation of benchmarking results in 2009.

Management expectations

Plant managers at all levels are responsible for supporting the identification, reporting and resolution of NM and LLE events, and for encouraging their staff to openly communicate with regard to problems encountered in their workplace or observed elsewhere. The purpose of dealing with operational events and their precursors is not to identify a guilty person, but instead to find out what happened, and how and why it happened, so that necessary corrective measures can be identified to prevent event recurrence or to mitigate consequences.

The prime goal of Mochovce NPP in the feedback area is to minimize the number of significant events and consequential events. A proactive approach in this area on behalf of the organization is a precondition to reaching this goal. The organization's preventive attitude is based on the use of opportunities to learn lessons by means of analyses and dealing with operational event precursors.

A major goal of the collection and analysis of LLEs and NMs is to maintain a certain level of risk awareness, especially when the occurrence of significant events in an organization is low. Permanent motivation is critical for safety culture and for the safe behaviour of personnel at all levels.

Overview of the programme

Identification and reporting

Mochovce NPP allows two reporting possibilities, ‘open’ and ‘confidential’. Use of the confidential channel is permitted only for NMs, and such reporting is accepted only under special conditions (i.e. when there is no violation and no malevolent action, and when reporting is done by the person who was ‘at the heart’ of the NM, not by somebody else who observed another’s unsafe behaviour).

Any employee who identifies a LLE or NM is obliged to report it to his or her supervisor or, if immediate action is needed, directly to the shift supervisor.

Screening

Screening for immediate response is undertaken by the shift supervisor. Screening for LLE or NM risk significance is done daily by the OE section and discussed at the daily screening meeting. An assessment of LLE and NM risk categories results from the screening. The following matrix is used for determination of a risk category:

Risk considered to be:			
High	C1	B1	A
Intermediate	D1	C2	B2
Low	E	D2	C3
	Low	Intermediate	High
	Recurrence probability		

Investigation

Analyses of LLEs and NMs in risk categories A, B1/B2 and C1 are performed by the OE section (approximately 15–20% of all reported LLEs and NMs). Such analysis is performed to the level of root causes (using the HPES, fault tree or TapRoot methodology).

The corrective actions and review board chair has the authority to decide on the investigation of complex LLE and NM events by a multidisciplinary working group.

Precursors in risk categories C2/C3, D1/D2 and E fall within the competence of a particular department which is responsible for event investigation based on the nature of the event. An appointed staff member of this department performs event analysis to the level of apparent causes and suggests corrective measures.

All investigations are done by personnel trained in RCA techniques.

Corrective actions

The CARB approves analysis results and decides on corrective actions related to events dealt with at this management level, including significant events, selected LLEs and NMs (risk categories A, B1/B2 and C1).

For LLEs and NMs in risk categories C2/C3, D1/D2 and E, corrective actions are approved by the relevant department head. He or she also ensures implementation of the measures. The board only takes into account analysis results and measures taken at a particular department level.

Corrective actions related to all events are tracked by the OE section, with a special focus on corrective actions taken to eliminate root causes (risk categories A, B1/B2 and C1). The status of such corrective actions is regularly reviewed by the CARB.

Trend analysis

Trend analysis of event codes (including LLEs and NMs) is done by the OE section. Results of trend analyses are presented in quarterly and annual reports, which are discussed and approved by the plant director.

Human related codes appointed to LLEs and NMs undergo trend analysis, and the results are used as one of the main inputs into a human performance improvement programme at the plant.

If a group of similar LLEs and NMs with human performance issues is identified, a just-in-time report is developed. Such a report (a summary of lessons learned from LLEs and NMs, or industry OE) is then used in pre-job briefings to increase personnel awareness of the potential risks connected with a task.

At Mochovce NPP, LLEs and NMs do not cover all problems reported by personnel. There is another low tier programme managed by the quality assurance (QA) department. Only minor quality non-conformances (without any actual risk) and suggestions for improvements can be reported in this programme (statistically, thousands per year).

Mochovce NPP uses the WANO coding system.

Key focus areas

Past

The reporting of NMs at Mochovce NPP was initiated in 2000, and a dedicated NM reporting system was established. The number of NM reports submitted within the system gradually increased, starting from several in 2000 to more than one hundred in 2003.

In addition to this system, there was also another system for the reporting of LLEs and significant (consequential) events. A different system implemented by the QA department was used to report suggestions for improvements, minor housekeeping issues and minor (without risk) quality non-conformances. However, the number of reported NM events related to human performance problems was considered to be relatively small (in relation to the number of consequential events due to human performance deficiencies). For this reason, in 2004 the plant initiated an improvement project for a LLE and NM programme with the support of an external consultant company.

Present

In 2004–2005, a special project supported by the DTI (United Kingdom) and an external consultant was undertaken, leading to the following improvements:

— A clear definition of NM was created.
— Improvements were made in the reporting form (clarifying expectations, what the ‘as found’ condition was, the risk generated by the gap, suggestions for improvement).
— Screening criteria were established for LLEs and NMs and a risk matrix was introduced.
— Investigation processes were improved through higher participation of other departments and broad training in RCA techniques.

— More stress was placed on positive reinforcement, improvement of recognition and reward strategies.
— The training of personnel in OE processes has improved, with a special focus on benefits generated by the LLE and NM system.

In 2006, an OSART mission recommended the improvement of LLE and NM reporting within the maintenance division.

Future

The implementation of recent benchmarking results will lead to an overall change in the organization of the CAP. As a result, functions currently covered by the OE section will be divided among two new sections:

— Continuous improvement section (seven positions): responsible for coordinating implementation of the CAP (feedback from internal events and their precursors within the plant);
— OE section (five positions): responsible for coordinating dissemination of lessons learned from both internal and external events.

In connection with this change, one electronic plant database will be established (all problems will be reported to this database).

Successes

— A NM was reported by a maintenance worker through a confidential channel. The NM was connected to a handling activity during adverse weather conditions (high wind speeds). A small crane was being used during the cleaning of an intake cooling water screen panel section. Due to the wind, the crane became dislodged from its rails, and the maintenance technician realized that there was a potential for equipment damage or personal injury. Lessons learned from the NM were used to modify the crane (improved resistance for operation in bad weather conditions), revise maintenance procedures to prohibit work in certain weather conditions, and improve training of maintenance staff.
— After completing maintenance on a pump, a field operator was ordered to energize the pump motor. By mistake, he energized an adjacent pump motor. The situation created the potential for injury of personnel. The field operator’s supervisor reported the incident when he realized the operator’s error. Lessons learned from the NM were used to improve shift communication practices.

Challenges

Despite many efforts to promote reporting of LLEs and NMs, problems continue. Consequently, some opportunities to avoid events with consequences have been missed. For example, a trap (a hole covered by a tin plate) existed on a maintenance shop roof, which created a risk of falling through the hole for people working on the roof. This trap was not reported, despite the fact that it had been identified. Eventually, an inspection technician, who was unaware of the trap, stepped on the tin plate and fell through the hole onto the shop floor below. As a consequence, he suffered serious injury.

Challenges for the future

— Maintaining and further improving the reporting culture and personnel morale in a changing organization;
— Implementing SAP nuclear: reorganization of the CAP and other relevant processes.

Good practices to share

All personnel receive a systematic 'education', including shift personnel (at least once a year) and daily personnel (once every three years).

Training courses consist of:

— Management policy (reporting expectations, 'just' culture);
— How to recognize LLEs and NMs;
— The process, from identification to resolution;
— Benefits of NM reporting;
— Good and bad examples (in-house as well as industrial): success stories, missed opportunities;
— Feedback from attendees: what to improve in the process.

Frequent critical benchmarking of the LLE and NM programme is required, including surveys with broad personnel participation to identify potential obstacles in programme effectiveness.

Annex III

TYPICAL EXAMPLES OF UNREPORTED ISSUES

Area	Brief description	Failed barriers and failed good work practices	Consequences
Management	Daily screening meeting failed to appropriately recognize the safety significance of a feed-water isolation valve problem.	Lack of knowledgeable personnel present at the daily screening meeting, failure of stand-in staff to adequately prepare for the meeting.	Potential to miss safety system operability issue.
Operations	During a routine changeover of a reactor auxiliary cooling water pump, operators inadvertently started to close the wrong pump discharge valve.	Operators failed to follow procedure step by step, inadequate self- and peer checking.	Potential for loss of cooling water with subsequent equipment damage.
Maintenance	Surface anomalies on new reactor feed pump seals on a BWR were identified just prior to installation.	Equipment receipt inspection, manufacturing process quality control.	Rework time, down power extension.
Programmes and procedures	Steps found to be missing in work control procedure for isolating a building steam heater.	Procedure validation process inadequate.	Work stopped to review and correct procedure, resulting in lost work time.
Equipment failure	Routine plant inspection tour revealed an unidentified failed interzone boundary personal radiation/ contamination hand, foot and clothing monitor.	Unanticipated equipment failure affecting many people.	Potential for workers to exit the controlled area zone without appropriate monitoring, potential spread of contamination beyond zone boundaries, lost work time for workers having to look for operable monitors.

Area	Brief description	Failed barriers and failed good work practices	Consequences
Human performance	Portable gamma alarm monitors inadvertently unplugged during work in a radiation area.	Situational awareness and questioning attitude not used, essential equipment plug not adequately tagged.	Lost time on job to correct the situation, potential for unplanned radiation dose uptake, worker protection inappropriately defeated.
Industrial safety	Workers were observed not properly attaching fall protection while working from scaffolds.	Supervisor oversight, worker knowledge, peer coaching, pre-job briefing, procedure review.	Workers unduly exposed to fall hazard. Downtime for working while corrective actions are implemented.
Radiation protection	Workers seen to exit radiation protection area without completing appropriate dressing and decontamination procedures.	Supervisor oversight, worker knowledge, peer coaching, pre-job briefing, procedure review.	Potential spread of radioactive contamination outside controlled areas.
Programmes and procedures	A system engineer specified work on a safety support system but was unaware of an undocumented physical change to the system. A shift supervisor caught the error before work commenced.	Configuration management problems, many undocumented physical changes and long existing temporary changes.	It was fortunate that the shift supervisor caught the error in the requested work, otherwise the safety support system would have been significantly impaired.

Area	Brief description	Failed barriers and failed good work practices	Consequences
Industrial safety	While working from a scaffold, a contract maintenance worker dropped a wrench from a height of 4.5 m.	Worker safety.	It was fortunate that nobody was in the fall line of the wrench, as that person could have received serious injury.
Chemistry	A chemistry technician selected the incorrect chemical to add to a primary coolant system, but a supervisor identified the issue before the chemical was added.	Self-checking.	Potential change in system parameters resulting in entry of an action level if the chemical had been added.

Annex IV

LADDER OF ACCOUNTABILITY[1]

The ladder of accountability describes eight levels of accountability (Fig. IV–1). The top four describe a stance focused on movement toward the future. The bottom four describe a stance generally focused on the past or on avoiding discomfort in the present.

This tool provides an organization and individuals with an effective way to look objectively at an issue that they are dealing with and to make some deliberate choices about how they want to handle it. The further up the ladder an organization or individual can move, the more choices will become available. The greater the percentage of people who choose stances at the top portion of the ladder, the greater the chance an organization has of collaborating and successfully attaining its goals.

FIG. IV–1. The ladder of accountability.

[1] The material in this annex is extracted from: RIDENOURE, R., Leadership for Smarties, Southern California Edison, Rosemead, CA (2009).

Annex V

WESTRUM'S CLASSIFICATION OF ORGANIZATIONAL TYPES

Westrum proposes that the handling of information and communication are key features of organizations. He has identified three different organizational types (or phases of organizational development); these are outlined in Table V–1.

TABLE V–1. WESTRUM'S CLASSIFICATION OF ORGANIZATIONAL TYPES

PATHOLOGICAL	BUREAUCRATIC	GENERATIVE
Do not want to know	May not find out	Actively seek information
Messengers are shot	Listened to if they arrive	Messengers are trained
Responsibility is shirked	Responsibility is compartmentalized	Responsibility is shared
Bridging is discouraged	Allowed but neglected	Bridging is rewarded
Failure is punished or covered up	Organization is just and merciful	Inquiry and redirection
New ideas are actively crushed	New ideas present problems	New ideas are welcomed

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Annex VI

HUDSON'S ORGANIZATIONAL CULTURE MATURITY LADDER

Figure VI–1 shows phases of organizational development according to Hudson's organizational culture maturity ladder. This model is particularly relevant to the prevailing culture necessary for successful implementation of an effective OE programme. In the context of this publication, the managerial challenge is to lead the development of an organization along these progressive steps and/or to maintain the 'generative' phase.

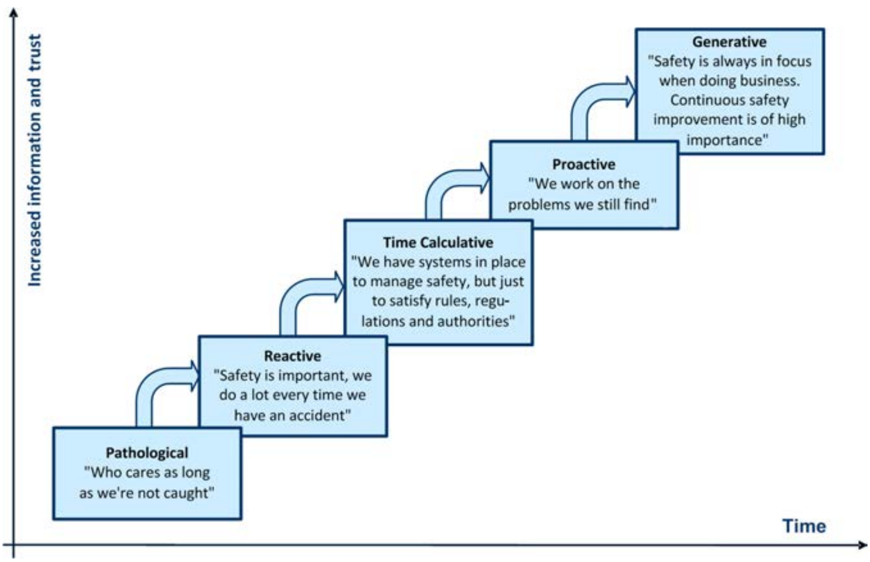

FIG. VI–1. Hudson's organizational culture maturity ladder.

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Annex VII

CULPABILITY ASSESSMENT

Figure VII–1 presents a decision tree for determining the culpability of unsafe acts.

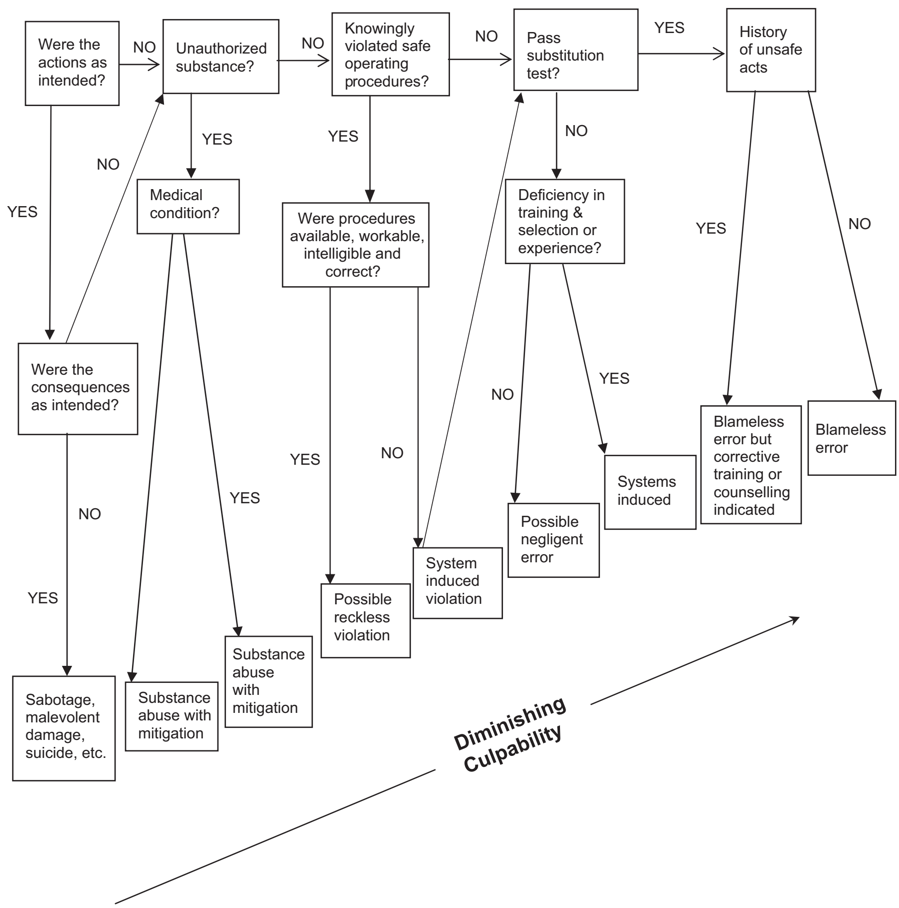

FIG. VII–1. A culpability decision tree.

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Annex VIII

THE DANISH SYSTEM FOR REPORTING OF AVIATION INCIDENTS[1]

VIII–1. BRIEF DESCRIPTION

In 2001, a new law was passed by the Danish Parliament mandating the establishment of a compulsory, strictly non-punitive, and strictly confidential system for the reporting of aviation incidents. A particular and perhaps unusual feature of this reporting system is that not only are employees (typically air traffic controllers and pilots) guaranteed strict immunity against penalties and disclosure but also any breach against the non-disclosure guarantee is made a punishable offence.

The re-engineered system in Denmark is a mandatory, non-punitive and strictly confidential system. The reporting system is mandatory in the sense that air traffic personnel are obliged to submit reports of events, and it is strictly non-punitive in the sense that personnel are guaranteed indemnity against prosecution or disciplinary actions for any event they have reported.

Furthermore, the reporting system is strictly confidential in the sense that the reporter's identity may not be revealed outside the agency dealing with occurrence reports. Reporters of incidents are assured immunity from any penal and disciplinary measure related to an incident if they submit a report within 72 hours of its occurrence and if it does not involve an accident or deliberate sabotage or negligence due to substance abuse (e.g. alcohol). Moreover, punitive measures are stipulated against any breach of the guaranteed confidentiality.

The important distinction between an anonymous and a confidential reporting system lies in the fact that with an anonymous reporting system reports are unidentifiable, while with confidential reports the reporter is known. An anonymous report offers no possibility to derive further facts in the investigation process. However, with a confidential system the reporter submits his or her name and can thus be contacted during the investigation process for further clarification and feedback purposes.

[1] The material in this annex is extracted from: EUROPEAN ORGANIZATION FOR THE SAFETY OF AIR NAVIGATION, EAM 2/GUI 6 — Establishment of 'Just Culture' Principles in ATM Safety Data Reporting and Assessment, EUROCONTROL, Brussels (2006).

VIII–2. THE LEGISLATIVE PROCESS IN DENMARK

In 2000, growing concerns about flight safety in Danish airspace were raised by the Danish Air Traffic Controllers Association. The concern was associated with losses of separation (incidents of aircraft flying too close together) which were not being reported due to a fear that the reporter would face sanctions, particularly if he or she were partly or fully responsible for the incident. The fear was real, since controllers had previously been prosecuted for such actions. Furthermore, the Danish press had in the same period been dealing aggressively with apparent breaches of flight safety within certain airlines. These two factors — punishment of air traffic controllers with fines or licence suspension and a focus by the press on aviation safety issues — had the effect of reducing the reporting of incidents.

The whole aviation system in Denmark suffered from this, with no lessons being learned or disseminated from these events. It ought to be added, however, that prior to 2000, the ‘culture of reporting’ in Denmark was comparable to most north-western European countries — some occurrences were reported, but there was an acknowledgement of ‘underreporting’. In contrast, Denmark’s neighbour, Sweden — which has approximately the same amount of civilian air traffic — reported a considerably larger number of flight safety occurrences than Denmark.

In 2000, in order to push for a change, the chairperson of the Danish Air Traffic Controllers Association decided to be entirely open about the then current obstacles to reporting. During an interview on national television, she described frankly how the system in place at that time was discouraging controllers from reporting. The journalist interviewing the chairperson had picked up on observations made by safety researchers that, as described above, Denmark had a much smaller number of occurrence reports than Sweden. Responding to the interviewer’s query as to why this was so, the chairperson proclaimed that losses of separation between aircraft went unreported simply due to the fact that controllers — for good reasons — feared retribution and disclosure. Moreover, she pointed out, flight safety was suffering as a consequence. These statements, broadcast on a prime time news programme, had the immediate effect of encouraging the Transportation Subcommittee of the Danish Parliament to ask representatives from the Danish Air Traffic Controllers Association to explain their case to the Committee. Following this work, the Committee spent several of their 2000–2001 sessions exploring various pieces of international legislation on the reporting and investigation of aviation incidents and accidents. As a result, in 2001, the Danish Government proposed a law that would make non-punitive, strictly confidential reporting possible.

The law grants freedom from prosecution, even if the reporter commits an erroneous act or omission that would normally be punishable. Furthermore, the reports from this scheme would be granted exemption from the provisions of the Freedom of Information Act. Investigators would, by law, be obliged to keep information from the reports undisclosed. However, the law would grant no immunity if gross negligence or substance abuse was present in the reported situations, and it would also be punishable by a fine not to report an incident in aviation.

In most democratic countries, the Freedom of Information Act is almost a sacred institution. This is also the case in Denmark. It was acknowledged by politicians and aviation specialists that the public had a right to know the facts about the level of safety in Danish aviation. In order to accommodate this, it was written in the law that the regulatory authority of Danish aviation, based on incoming reports, is required to publish overview statistics twice a year, based on de-identified data from these reports.

This law was passed unanimously by the Danish Parliament in May 2001. Compared with other legal norms in Denmark, and probably in most countries, this law is unique in the sense that it is the only law in Denmark that guarantees immunity from prosecution when an otherwise punishable offence has been committed. During the legislative process, public interest in the matter was surprisingly low, and apart from a few editorials in national newspapers, the matter was not commented on. After the regulatory authority, based on incoming flight safety reports, made its first statement, public interest increased. However, the media were mainly interested not in the system itself, but in the apparently unsafe nature of Danish aviation.

VIII–3. THE IMPLEMENTATION PROCESS

After the law was passed, the Danish aviation regulatory authority body, Statens Luftfartsvæsen, implementated the regulatory framework. The regulatory authority subsequently issued instructions to the following groups, stating that for these five categories of licence holders it would be mandatory to follow the reporting system:

— Pilots holding an air transportation pilot’s licence;
— Air traffic controllers;
— Certified aircraft mechanics;
— Certified airports;
— Pilots holding a general aviation pilot’s licence.

Since both pilots and air traffic controllers now have to report various situations according to the reporting system, it is obvious that these two categories will sometimes be reporting situations basically created by the other. This will not incriminate either, as long as each professional abides by the obligation of reporting. This means that, for example, a situation created by air traffic control and reported by a pilot will not incriminate the controller as long as the controller reports the same situation.

In order to make it clear which situations these personnel were obliged to report, the regulatory authority passed guidance material to each of the five categories. Since the situations that could pose a threat to aviation are different for each category, each has its own set of descriptions of mandatory reportable situations. In the following sections, only the material and the process concerning air traffic control will be dealt with.

VIII–4. REPORTING AND ASSESSMENT OF SAFETY OCCURRENCES IN AIR TRAFFIC MANAGEMENT

For air traffic control, the regulatory authority issued reporting categories that were derived from EUROCONTROL requirement ESARR 2.

Within Naviair (the Danish air traffic control service provider employing all air traffic controllers in Denmark), a high level decision was made to actively support the implementation process of this new reporting system. This decision was not made solely because it was mandatory, but also because management foresaw a benefit to the company's main product, flight safety. As a consequence, every air traffic controller received a letter from management explaining the new system and stating Naviair's commitment to enhancing flight safety through the reporting and analysis of safety related events. The incident investigators responsible for implementation of the new system were given the task of communicating the change, and were also given a full mandate and support by management.

An extensive briefing campaign was carried out in order to inform all air traffic controllers about the new system. In the briefing process, controllers expressed many concerns, particularly pertaining to confidentiality and the non-punitive aspect of the system. These concerns were due to the existing culture and were all anticipated. Typical questions asked during the implementation process included:

— Can we trust this new system?
— What will it be used for?
— Why do we have more non-productive paperwork?
— We just handle the situations, so why report them?

They were dealt with by explaining the intentions of the law governing the reporting system: the law would not grant media or others access to the reports, and it would secure freedom from prosecution. Furthermore, it was emphasized that no major enhancement of flight safety would be possible if no information about existing hazards was gathered and disseminated, and that the reporting system might ultimately be able to explain and hopefully eliminate the flaws that everybody recognized in everyday operations. Naviair basically asked the air traffic controllers to trust them, and to take ownership of flight safety. In return, Naviair would try to deal effectively with flight safety.

VIII–5. RESULTS

The reporting system started to operate on 15 August 2001. During the first 24 hours after its introduction, Naviair received 20 reports from air traffic controllers. In the first year after the reporting system was put into place, Naviair received 980 reports, compared with 15 the previous year.

Still, the numbers from the new and the old 12 month period cannot be compared directly.

With the new reporting system, air traffic controllers became obliged to report instances that were not compulsory to report beforehand. So the best comparison would be to compare the numbers of reported losses of separation between aircraft (which were the only mandatory reportable occurrences before implementation of the new system). This comparison is fair and informative, and it serves to show the quite dramatic change in reporting culture, not least because air traffic controllers were punished for the same situations beforehand.

Losses of separation averaged approximately 15 a year before implementation, whereas two years after implementation 40–50 losses of separation were reported per year.

It is important to mention that any company management that puts a system like this in place has to prepare for new and maybe unpopular information. It may come as a surprise for the management of any company when more breaches of safety are being reported. It is very important that this new knowledge not be seen as a sign that safety is sliding. Rather, it is better interpreted as an uncovering of things that have existed and gone unreported for years. The paradox remains, however, that the safest companies will initially be viewed as unsafe companies due to their willingness to elicit a greater number of reports. In the interim, it takes courage to be safe.

VIII–6. INVESTIGATION

The investigation process is one of the most important parts of a safety culture. It is of the utmost importance that a company that puts a confidential, non-punitive reporting system in place be professionally prepared to handle the challenge, and a formal process has to be set up to handle the resulting reports.

The reports received by Naviair (which are to be submitted within a maximum of 72 hours after an incident) vary in content from small deviations or technical malfunctions to serious losses of separation. Naturally, not all situations will receive the same amount of attention and interest from investigators.

In order to gain maximum flight safety benefit, Naviair has set up priorities for report handling. In general, all reports are evaluated. This evaluation attempts to establish whether immediate action is required. These situations would typically be cases of losses of separation between aircraft, or serious procedural or technical issues.

All losses of separation between aircraft are investigated thoroughly. These incidents are categorized and include the following:

— Separation minima infringement;
— Runway incursion where avoidance action was necessary;
— Inadequate separation between aircraft.

Each investigation includes gathering of all factual data such as voice recordings, radar recordings, flight progress strips, etc. After factual data have been collected and analysed, an investigator carries out interviews face to face with the involved controller(s) and other personnel relevant to the situation. The interviews need to be carried out with a human factor focus based on the HEIDI taxonomy developed by EUROCONTROL.

When data gathering and interviews are complete, the investigator produces a written report of the incident, which is to be completed within a maximum of ten weeks. The ultimate purpose of the report is to recommend changes to prevent similar incidents.

In Naviair, incident investigators receive training in both investigation techniques and human factors, and they are required to maintain their operational status, which has proven useful for maintaining credibility among controllers. Furthermore, it is recognized that it is not possible to produce a meaningful incident report without current knowledge of air traffic control operations.

The final report on incidents follows the same format in every investigation. The report describes the factual circumstances and contains an investigator’s assessment of the following elements:

— Aircraft proximity and avoidance manoeuvres;
— Safety nets: their impact on and relevance to the incident;
— System aspects;
— Human factors;
— Procedures;
— Conclusion;
— Recommendations.

In order to evaluate the effects of the reporting system, it helps to look into the content of these incoming reports and note the effect that the investigation of these reports has had.

VIII–7. FLIGHT SAFETY PARTNERSHIP

Another flight safety enhancing element that has developed since the new reporting system was implemented is the sharing of flight safety knowledge. As a result of investigations of incoming reports, Naviair quickly realized that air traffic control cannot handle flight safety alone. Many potentially hazardous situations between aircraft arise as a consequence of the interface between air traffic controllers and pilots (misuse of phraseology, different understandings of procedures, different expectations, etc.). If there is to be any hope of making a new breakthrough in flight safety, it will be important to look at flight safety as a shared process.

In order to deal more effectively with flight safety, Naviair decided to establish a Flight Safety Forum. Naviair subsequently invited flight safety officers from all major Danish airlines to participate in discussion and knowledge sharing of flight safety relevant information. Everybody involved accepted this invitation; as a result, the Forum meets twice a year and addresses operational flight safety in Danish airspace. Furthermore, it has been decided to share this information for use in incident investigation.

VIII–8. SAFETY IMPROVEMENT

It is worth repeating that the overall goal of establishing a flight safety reporting system is to improve flight safety. In turn, the value of such a system has to be viewed with regard to its effect on flight safety. This can sometimes be a difficult task to perform, as a prevented accident will never appear in any statistics.

When the changes made to the Danish system (machine/procedure/human) since the reporting system was implemented are examined, it is obvious that improvements have been made. Before implementation of the reporting system, many flight safety relevant observations were reported, but to different departments in Naviair, thus eliminating the advantage of focused information gathering and dissemination.

VIII–9. CONCLUSION

Today, Naviair feels confident that the system put in place is solidly founded within the Danish air traffic control system. This assessment is based on what can be heard when listening to discussions among controllers and support staff, which take place on and off the record, as well as on the amount and content of the reports received.

Of course, the system has experienced difficulties. Sometimes air traffic controllers do feel blamed when they learn of an investigation conclusion. Equally, in the minds of the individuals involved, a non-punitive confidential culture may appear to be a general amnesty for every mistake made; but that is not the case. Most of the investigated incidents have human mistakes as their root cause. That fact can be hard to be face up to, and in such situations it is important to confront the responsible individual in a way that inspires proactiveness, for both the organization and the individual, so that both will learn.

What made all this possible? First of all it is important that a legal framework is in place to run a reporting system. Even the most well meaning management will have problems instilling trust if legal action can still be taken against employees.

Second, the management of any company in a safety critical business — whether in aviation, medical care, power generation or the nuclear industry — has to be committed. Safety starts at the top.

In order to give the air traffic controllers themselves the ownership of flight safety, it is very important that the people who are communicating safety have a professional background. Many feelings arise, and discussions follow, when endeavouring to communicate flight safety. These discussions and questions have to be answered by people who have ‘felt’ the business themselves. Management has to show support and be visible in safety campaigns, but professional discussions have to take place among professionals.

The ultimate test of any non-punitive, confidential reporting system (the legal framework, the confidentiality, the psychology) will come if a country running such a system experiences an aviation disaster with loss of life. When this happens, everything takes a new and unknown course. To prepare for this, it is important to focus on the fact that without aviation safety reporting systems, the likelihood of disasters is much greater.

Annex IX

EXAMPLES OF TREND ANALYSIS SUCCESS AT EXELON NUCLEAR

In 2006, Exelon Nuclear performed a common cause analysis as the result of an adverse trend in equipment reliability. One of the common causes identified was equipment failures caused by latent manufacturing defects. As a result, a new quality based programme was initiated called the Parts Quality Initiative (PQI). The essence of this programme is to review both internal and external OE for manufacturing related issues and to analyse these issues for trends. Once a trend is identified, a condition report is generated, the trend is evaluated and actions are taken to prevent this manufacturing defect from affecting other plants, systems or components.

Corrective actions from these evaluated trends will influence which items will be procured in the future, and verify that items with identified defects are not contained within the existing inventory. Exhibited latent manufacturing defects will be related back to the suppliers of deficient parts, with the issue being used in the assessment of a supplier's past performance when negotiating a new contract with that supplier.

Each month, condition reports of all equipment failures of critical components and parts are reviewed for emerging trends. These condition reports usually contain failures that have occurred during maintenance or pre-receipt testing as well as other NMs and significant events that have occurred during the previous month.

As a result of this programme, there has been an improvement in plant reliability, which has manifested itself through a decrease in equipment failures caused by latent manufacturing defects. In the past three years, there have been almost no equipment failures caused by recent manufacturing defects that have impacted plant production. The following are some examples of instances where this programme has prevented more significant events that could have caused generation losses:

— A trend was identified within Exelon condition reports regarding an anti-rotation pin that the valve supplier inadvertently omitted from various check valves used in the extraction steam system. As a result of the identification of this trend, a review of this model of check valve was performed in the inventory system, and these valves were found staged in the outage parts about to be installed at both Byron and Oyster Creek stations in the upcoming autumn outages. Previously, at a different station, a failure of these check valves due to the missing anti-rotation pin had resulted in the valve disc separating from the stem and the disc becoming lodged in the extraction steam line, resulting in a two day outage. Trend analysis of these failures and subsequent removal of these valves from the inventory prevented a future two day unplanned outage, saving the company more than US $2 million in lost generation and indirect costs, as well as improving nuclear safety by preventing an unplanned reactor trip.

— A trend was identified at the Braidwood Station regarding several failures of feedwater heater air supply valves. Further evaluation of this trend revealed that foreign material (brass chips) had been left inside the valves by the manufacturer. It was further ascertained that the brass chips had migrated and affected the valve seating function and could migrate further into the positioner and impact feedwater valve operations, potentially affecting generation owing to a loss of feedwater heaters. An inventory check indicated that three other stations also had these valves; a further check revealed that the valves also contained the foreign material, which could have affected those plants as well. The valves were removed from the inventory, and new valves were procured which were verified not to contain the foreign material. Previous positioner failure issues had resulted in 3000 MW·h (US $150 000) of lost generation due to a derating during the failures.

— During the trend identification and analysis of proximity switch failures within the Exelon system, it was determined that switch failures had occurred because the manufacturer had wired the switches backwards. As a result, corrective actions, including reviewing inventory for this type of proximity switch, were undertaken in the Exelon inventory system. One of these switches was found as it was about to be installed at a station in a high radiation area. A new switch was procured and the defective switch was replaced. Failure of the defective proximity switch would have delayed operation of the switch, and would have resulted in a production risk evolution in the summer. Replacing the defective switch would have resulted in an unnecessary additional radiation dose received by workers due to the high radiation area it was located in.

The parts quality low level trend analysis process has been recognized as a good practice by the nuclear industry, INPO and the Electric Power Research Institute.

Annex X

THE CORRELATION BETWEEN ACCIDENT RATES AND COSTS[1]

This review of the US nuclear power industry began with the following rhetorical question: "What is the actual cost to an employer of an accident?" The intention was to immediately start the reader thinking about the benefit to cost trade-off in the implementation of accident reduction activities. The primary hypothesis of the review was that there is a set of accident investigation practices that yield top quartile organizational safety performance. The secondary hypothesis was that organizational influences have a greater impact on accident rates than investigation practices. These activities are within the span of control of company owners and managers and thus represent opportunities for cost savings. This review provides direct correlation to cost benefits associated with the collection and analysis of LLE and NM data.

A descriptive survey was developed to collect information about safety performance (in the form of OSHA Form 300A data) and accident investigation practices. Accident investigation practice questions were developed based on the related literature and the author's firsthand experience from over 15 years of accident and organization investigation. The target population for this review was manufacturers in northeast Pennsylvania. To be more exact, the review involved manufacturers with more than 20 employees in 16 counties in northeast Pennsylvania. The descriptive survey was mailed to 972 manufacturing companies identified in the 16 county target region in March 2006. As of 1 June 2006, 54 organizations (5.5%) had provided a response with complete survey data. The responses were evaluated and determined to be representative of manufacturers in Pennsylvania, as well as technology and other industries.

The direct cost to employers of injuries is staggering. In a 2004 report, Liberty Mutual reported that serious work related injuries cost American employers US $49.6 billion in 2002 (Liberty Mutual, 2004). The report only included 'serious workplace injuries', which were defined as events through which the worker missed six or more days. In the 2005 article titled 'Reduce Medical Claims: Workplace Ergonomics', the author cites a much higher figure that encompasses all injuries: "Six million workers suffer workplace injuries each year at a cost to US business of more than US $125 billion". Using the latter statistic, the average direct cost per injury is nearly US $21 000. These numbers

[1] This review of the US Nuclear Power Industry is by T.S. Tonkinson. The views expressed do not necessarily reflect those of the International Atomic Energy Agency or its Member States.

represent direct costs to employers, such as medical expenses and paid time off. While this review focused on industrial accidents, a direct correlation has long being established within the nuclear industry, via the event pyramid, to costs associated with other types of LLE and NM.

The actual indirect costs to employers from accidents are not well defined or monitored. In one study, it was estimated that “each $1 of direct costs generated between US $3 and US $5 of indirect costs”. Assuming this relationship is accurate, consider several of the direct cost figures discussed previously. The Liberty Mutual figure of US $49.6 billion in direct costs in 2002 would involve between US $150 billion and $250 billion in indirect costs. The total lost time value of US $125 billion in direct costs would involve between US $375 billion and US $625 billion in indirect costs. The ‘per injury’ value of US $21 000 in direct costs would involve US $63 000 to US $105 000 in indirect costs.

The intention of the data gathering and analysis was to explore the relationship between accident rates and accident investigation practices in order to deduce a set of practices associated with statistically better safety performance.

X–1. FINDINGS

Table X–1 provides a summary of the safety performance data received in the 54 completed surveys. Actual OSHA recordable injury and OSHA lost work day rates were calculated. To analyse the significance of the responses to the accident investigation practice questions, the responses were sorted into quartiles based on the calculated OSHA recordable accident rate. Quartile breaks are provided in Table X–1.

X–2. CONCLUSIONS

The results of the review confirm the primary hypothesis that there is a set of investigation practices that is correlated with better safety performance. The following practices are considered to be critical elements of an effective accident investigation programme:

— It is necessary for an organization to have a defined, formal investigation process: The expectations, prescribed methods and reporting methods are to be described in writing and be made available in a readily retrievable form. In addition to tactical ‘how to’ information, management expectations about the importance of accident investigation, openness of personnel to responding and the need to support such a programme ought to also be documented.

TABLE X–1. SUMMARY OF ACCIDENT DATA PROVIDED BY RESPONDENTS

Average number of employees	206
Average number of hours worked in 2005	422 183
Average OSHA recordable injury rate	7.47
1st quartile range — OSHA recordable injury rate	0.00–1.46
4th quartile range — OSHA recordable injury rate	9.09–55.78
Average OSHA lost work day case rate	1.97
1st quartile range of OSHA lost work day case rate	0.00–0.00
4th quartile range of OSHA lost work day case rate	3.07–16.40

— It is necessary for organizations to investigate more than just OSHA recordable accidents: The causes of NMs and minor consequence accidents (which equates to NMs and LLEs) are the same as the causes of serious accidents. The difference in consequences is a factor of coincidence of circumstances. Companies can reduce their accident rates by identifying the causes of lower level issues and eliminating them (resulting in improved safety, plant performance and cost reduction).

— Accident investigators are to have formal training: This is necessary to convey prescribed techniques, management expectations and interpersonal skills. Accident investigation is as much an art as it is a skill; therefore, investigators need practice (which is another reason for investigating more than just serious accidents). In addition to training, some form of reinforcement is also necessary.

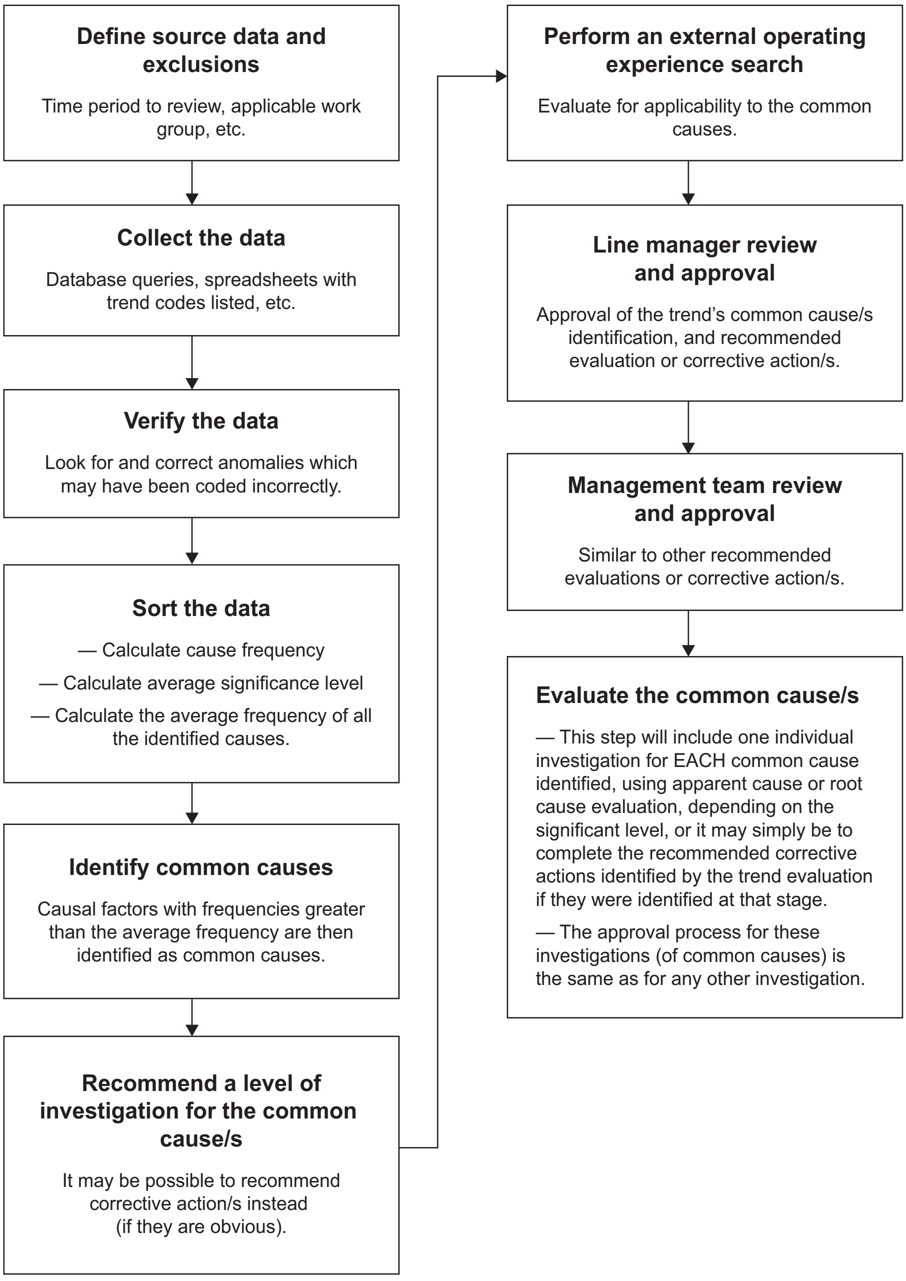
— Root cause analysis (RCA) is necessary for understanding the deeper reasons behind events: RCA is needed so that appropriate actions can be developed to prevent recurrence. It is important for causal analysis to include all factors, including human behaviour and organizational influences.

— Effective accident investigation programmes have some method of tracking the actions to closure: Several case study publications emphasize the applied importance of corrective action tracking and closure.

— Accident and NM investigation reports need to be used as communication tools for sharing lessons learned from events: An organization can use these reports to re-emphasize management expectations, reinforce good practices and warn other employees of situations that may adversely affect them.

Annex XI

EXAMPLE OF A TREND PROCESS FLOW SHEET



Annex XII

BRUCE POWER TREND EVALUATION CHECK SHEET

Quality Checklist	Yes	No
Does the trend evaluation clearly define the scope and impact of the trend and the data range?	☐	☐
Are the data points related in a logical manner to ensure an accurate outcome?	☐	☐
Are causal factors consistently identified for each data point?	☐	☐
Has the average frequency been calculated properly?	☐	☐
Are common causes identified or if not is the basis acceptable?	☐	☐
Have internal or external OPEX been identified that match the common causes?	☐	☐
Is the disposition adequate to ensure that further actions taken will be thoroughly identified?	☐	☐
Are event codes and common causal factor codes listed and has the SCR been updated with the codes?	☐	☐
Has the responsible manager (or delegate) approved the trend evaluation?	☐	☐
Has the "new" SCR(s) been created and SCR number(s) documented in the trend evaluation?	☐	☐
Approval *Please ensure this evaluation has been approved by the responsible manager or designee. Approval cannot be delegated below the level of section manager.* **Approved by:** ______________________________ **Date:** ____________ Signature		

Annex XIII

GOOD PRACTICE ON SHARING OF NM INFORMATION

XIII–1. SHARING INFORMATION THROUGH THE NEAR MISS REPORTING CONFERENCE

XIII–1.1. Brief description of NPP

The Mihama NPP has three PWRs of 340 MW(e), 500 MW(e) and 826 MW(e).

XIII–1.2. Contents of good practice

Reinforcement of NM activity is aimed at facilitating efforts to mature the safety culture. It has been in place since 2008, although the activity itself has long been executed.

To stimulate reporting, the plant requests information, allowing anonymity. As a result, 1242 NM events were reported in 2008 and 1432 events were reported in 2009.

NM information that needs to be widely shared with other workplaces is compiled, reported and distributed at the Near Miss Reporting Conference, jointly organized by the Mihama NPP and contractors (members of the Safety and Health Council). This conference is held twice a year.

At a 2009 conference, the Mihama NPP and contractors presented and shared about 104 cases. Some examples presented at the conference are as follows:

— Example 1: Possible entanglement of a leather face cover for welding with a rolling grinder. A craftsman who had hung a leather face cover around his neck tried to grind welding equipment. He got close to the rolling grinder. His leather face cover could been pulled in by the grinder.
— Example 2: Possibility of cutting an electric cable. An engineer tried to remove an electric lighting panel for repair. He disconnected all electric cables in the panel but missed one cable which went through the panel. Fortunately, he realized his mistake and removed the cable. If he had not realized the situation, the cable might have been cut/damaged.

— Example 3: Vacuum in a pure water tank while draining its contents. The operator tried to drain the water from a pure water tank. He confirmed that the vent line was open. After he started the draining operation, he noticed that the middle part of the tank was slightly deformed. Thus, he stopped the draining and checked the tank and its piping. As a result, he found a clogged mesh in the vent line. The clogging material was granular sand which had been used during sand blasting of the tank.

There is an award system for individuals and contractors at the conference, which is held twice a year. At each conference, eight or nine individuals and one contractor are recognized.

In the case of individuals, an award committee chooses good presentations at the conference.

For contractors, the award is based on analysis of various established indicators. These indicators examine a variety of factors, such as the frequency of internal meetings, including pre-job briefings, the frequency of internal training seminars, the amount of feedback (both facilities and practices) on NMs and the number of presentations given at a conference. The award system also takes into account the number of persons employed by each contractor, so that smaller contractors can also be rewarded.

The above information NM is also utilized among contractors in pre-job briefings on the site and in their internal seminars.

All of these activities have aided in the prevention of non-conformances and industrial accidents at the Mihama NPP.

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