INSAG-13

Management of Operational Safety in Nuclear Power Plants

INSAG-13

A REPORT BY THE
INTERNATIONAL NUCLEAR SAFETY ADVISORY GROUP

INSAG

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The Agency's Statute was approved on 23 October 1956 by the Conference on the Statute of the IAEA held at United Nations Headquarters, New York; it entered into force on 29 July 1957. The Headquarters of the Agency are situated in Vienna. Its principal objective is "to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world''.

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A report by the
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INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA, 1999

The International Nuclear Safety Advisory Group (INSAG) is an advisory group to the Director General of the International Atomic Energy Agency, whose main functions are:

(1) To provide a forum for the exchange of information on generic nuclear safety issues of international significance;
(2) To identify important current nuclear safety issues and to draw conclusions on the basis of the results of nuclear safety activities within the IAEA and of other information;
(3) To give advice on nuclear safety issues in which an exchange of information and/or additional efforts may be required;
(4) To formulate, where possible, commonly shared safety concepts.

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FOREWORD

by Mohamed ElBaradei
Director General

The International Atomic Energy Agency's activities relating to nuclear safety are based upon a number of premises. First and foremost, each Member State bears full responsibility for the safety of its nuclear facilities. States can be advised, but they cannot be relieved of this responsibility. Secondly, much can be gained by exchanging experience; lessons learned can prevent accidents. Finally, the image of nuclear safety is international; a serious accident anywhere affects the public's view of nuclear power everywhere.

With the intention of strengthening its contribution to ensuring the safety of nuclear power plants, the IAEA established the International Nuclear Safety Advisory Group (INSAG), whose duties include serving as a forum for the exchange of information on nuclear safety issues of international significance and formulating, where possible, commonly shared safety principles.

Engineering issues have received close attention from the nuclear community over many years. However, it is only in the last decade or so that organizational and cultural issues have been identified as vital to achieving safe operation. INSAG's publication No. 4 has been widely recognized as a milestone in advancing thinking about safety culture in the nuclear community and more widely. The present report deals with the framework for safety management that is necessary in organizations in order to promote safety culture. It deals with the general principles underlying the management of operational safety in a systematic way and provides guidance on good practices. It also draws on the results of audits and reviews to highlight how shortfalls in safety management have led to incidents at nuclear power plants. In addition, several specific issues are raised which are particularly topical in view of organizational changes that are taking place in the nuclear industry in various countries. Advice is given on how safety can be managed during organizational change, how safety performance can be effectively monitored and how declining performance can be detected at an early stage so that no significant safety concerns arise.

The report is intended primarily for managers and others involved in the organization and conduct of safety related activities at nuclear power plants, but it will also be of interest to regulators and others.

I am pleased to have received this report and am happy to release it to a wider audience.

CONTENTS

1. INTRODUCTION

1. There is increasing recognition of the importance of a strong safety culture to ensure that high standards of safety are achieved by both organizations and individuals. This was recognized by INSAG in its report on Basic Safety Principles for Nuclear Power Plants, 75-INSAG-3 [1].

2. The term ‘safety culture’ was expanded upon in a subsequent INSAG report, 75-INSAG-4 [2], which set out the universal features of a strong safety culture. The report emphasized that safety culture is both attitudinal as well as structural and relates to both organizations and individuals. The term ‘organization’ is used for the company or utility responsible for the operation of one or more nuclear power plants. The structural aspect of safety culture comprises the organization’s arrangements for safety, which is commonly described as the safety management system for the organization. ‘Management’ is used to mean the administration of the organization.

3. Organizations having a strong safety culture will have an effective safety management system with the support and ownership of all staff. However, the safety management system has a broader role in that it provides a framework by means of which the organization ensures good safety performance throughout the planning, control and supervision of safety related activities. The safety management system, in turn, provides a means by which the organization promotes and supports a strong safety culture. In particular, the system will shape the environment in which people work and thus influence their behaviour and attitudes to safety. The safety management system is thus generally considered to be an integral part of the organization’s quality management system, provided to ensure the quality of all aspects of nuclear power plant operations, including safety. However, the existence of a quality management system does not in itself ensure that there is an effective safety management system, since there is a requirement to ensure that the required arrangements for safety have been identified and implemented.

4. The purpose of this report is to build upon the ideas outlined in 75-INSAG-4 and to develop a set of universal features for an effective safety management system in order to develop a common understanding. This is based on best practices in quality assurance and management systems set out in other IAEA publications such as Safety Series 50-C/SG-Q [3]. The report recognizes the crucial importance of the commitment of individuals in the organization in ensuring the effective implementation of a safety management system.

5. The focus of the report is directed towards operating nuclear power plants and utilities but will also have application in other nuclear organizations. The report does

not attempt to describe in detail the required arrangements for the management of safety, as these will need to reflect the particular legislative requirements in the respective country and the culture[1] of the organization.

6. The report also provides guidance on various topics of current interest concerning the management of safety, including:

- introducing a safety management system;
- management of safety during organizational change (including personnel changes);
- monitoring effectiveness using performance measures;
- identifying declining safety performance.

In addition, Appendix I provides a set of questions by which an organization can make an internal judgement on the effectiveness of its safety management arrangements. It is important to supplement such internal benchmarking with periodic external peer reviews. Thus the Annex provides examples of events brought about by weaknesses in the safety management system, to illustrate the principles described in the report.

2. DEFINITION OF THE SAFETY MANAGEMENT SYSTEM

7. *The safety management system comprises those arrangements made by the organization for the management of safety in order to promote a strong safety culture and achieve good safety performance.*

8. The safety management system has two general aims:

- to improve the safety performance of the organization through the planning, control and supervision of safety related activities in normal, transient and emergency situations; and
- to foster and support a strong safety culture through the development and reinforcement of good safety attitudes and behaviour in individuals and teams so as to allow them to carry out their tasks safely.

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[1] The culture of the organization comprises the mix of shared values, attitudes and patterns of behaviour that give the organization its particular character. Put simply, it is ‘the way we do things round here’.

9. The term ‘safety management system’ should not be taken to suggest that safety is managed separately from other business activities. Neither should it be seen as an optional extra. Safety is an integral component of the way the whole organization is managed and must have the involvement and active participation of all staff. Consequently, the organization’s safety management system is generally considered to be an integral part of its quality management system. In particular, the documented arrangements for the management of safety are likely to form part of the documentation for the organization’s quality system. It is important that the documentation for the quality system cover all safety related activities within the organization. The associated quality assurance assessments (e.g. QA audits) carried out will provide one of a number of mechanisms to judge the effectiveness of the safety management system.

10. The safety management system embraces all those arrangements that are needed to ensure that safety is properly managed. It will comprise some arrangements that are primarily provided in the interests of safety, for example a permit for work system, systems for the review and authorization of plant modifications and the setting up of nuclear safety committees. The safety management system will also involve arrangements that contribute to other business objectives as well as to safety, for example the provision of competent staff. The arrangements to co-ordinate with external organizations such as plant vendors, suppliers and contractors are also an important part of any safety management system.

11. The arrangements for the management of safety are formally documented in most circumstances. However, the level of detail to which the arrangements need to be formalized depends on their importance and the size and culture of the organization. Examples of formally documented arrangements are likely to include those for the control of plant modifications. Examples of informal arrangements are likely to include aspects such as the reinforcement of good practices by supervisors.

3. GENERAL FEATURES OF A SAFETY MANAGEMENT SYSTEM

3.1. INTRODUCTION

12. Safety is primarily the responsibility of the plant operating organization. To discharge this responsibility, the operating organization needs to establish an effective safety management system. This is the essence of what is often referred to as self-regulation. The system developed needs to comply with the requirements of

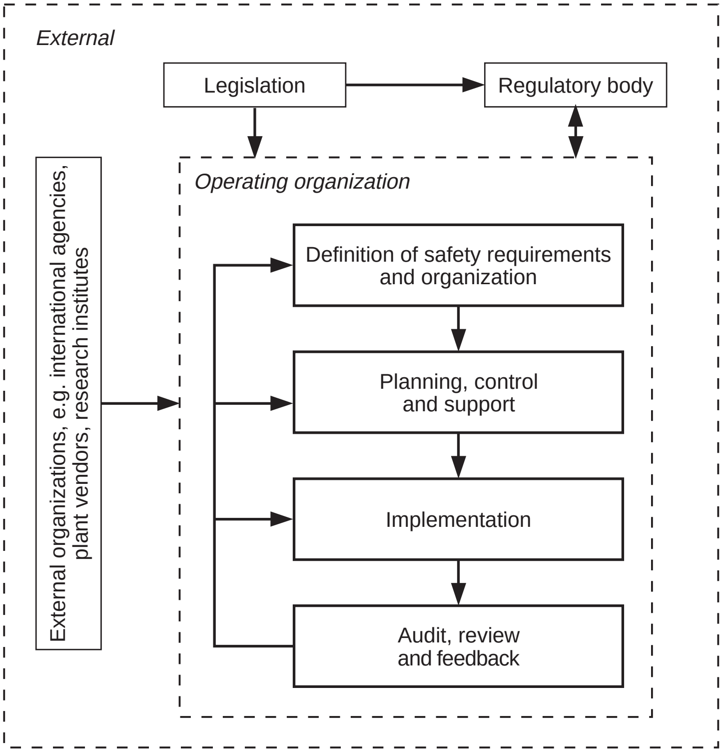

FIG. 1. Illustration of the framework for safety management.

legislation and the relevant regulatory bodies. The overall objective is to provide assurance that there is protection of individuals, the public and the environment. The basic framework for a self-regulating safety management system has four main elements, as illustrated in Fig. 1. This framework does not prescribe the most appropriate organizational structure, which will depend on other factors such as the size and culture of the organization:

— ‘*Definition of safety requirements and organization*’ involves the organization determining its policy for safety and specifying the main responsibilities and activities required to ensure safety and to satisfy legal, regulatory and company requirements.
— ‘*Planning, control and support*’ involves the organization determining the arrangements to ensure that the required activities are implemented safely.
— ‘*Implementation*’ involves individuals carrying out their tasks safely and successfully.

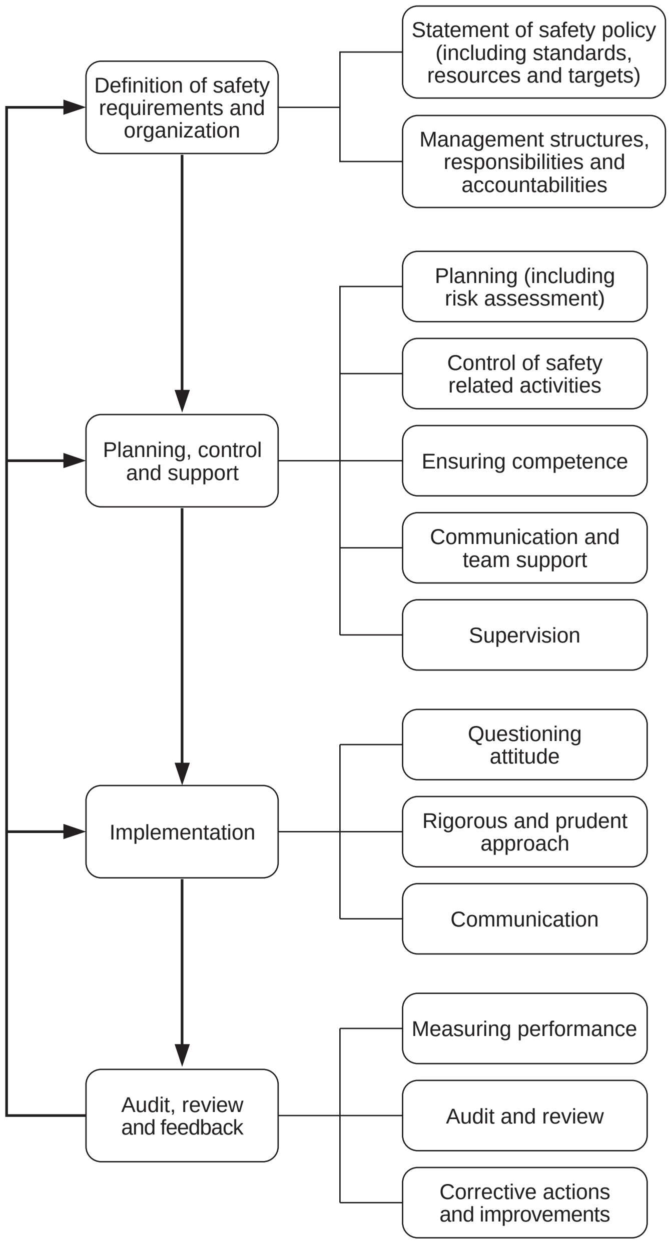

FIG. 2. Illustration of the components of safety management.

— ‘Audit, review and feedback’ involves the organization confirming both the achievements of its plans and the application of its standards, and improving safety by learning from its experience and that of others.

13. Figure 1 also shows the communication links between the operating organization and external organizations. In particular, these are important in ensuring that the requirements of legislation and regulatory bodies are communicated to the operating organization and to provide the necessary assurance to the regulatory body that high standards of safety are being achieved.

14. Figure 2 illustrates the major components of a safety management system, associated with each element in Fig. 1. These components are discussed below.

3.2. ROLE OF THE REGULATOR

15. *The regulatory body promotes an effective safety management system in the operating organization by ensuring that there is critical self-assessment and correction (described as self-regulation) and avoids acting in a manner that diminishes the responsibility for safety of the regulated organization.*

16. The body given the responsibility by the government to regulate the safety of nuclear plants has a significant influence on how operating organizations manage safety. The regulator ensures that the operating organization has an effective self-regulating safety management system and the regulatory body monitors the effectiveness of the organization’s safety management system as part of its scrutiny of safety performance. It is thus important that the regulatory body or bodies maintain open channels of communication with operating organizations.

17. The regulatory body monitors the performance of the organization and takes action if ever the safety management system becomes ineffective or the safety performance of the organization declines. The regulatory body needs to be technically competent, and will be most effective if it works in a manner that is non-bureaucratic and avoids excessive detailed regulation. Furthermore, the regulatory body should not exercise direct control over the management of safety within the operating organization or impose detailed requirements on the form of the organization’s safety management system. This could be counterproductive by weakening the system of self-regulation and diminishing and diluting the responsibility for safety assumed by the operating organization.

3.3. DEFINITION OF SAFETY REQUIREMENTS AND ORGANIZATION

18. *There exists a clear safety management framework within the organization with well defined safety requirements specifying the responsibilities and activities required to ensure safety and to satisfy legal and regulatory requirements as well as those of the operating organization.*

3.3.1. Statement of safety policy (including standards, resources and targets)

19. *A clear safety policy is developed which demonstrates the organization's commitment to high safety performance. It is supported by the provision of safety standards and targets and the resources necessary to achieve these.*

20. Nuclear plant operators will give safety the highest priority and this commitment may be expressed in a vision or mission statement setting out the business aims for the organization. It is important that the policy is demanding but nonetheless realistic and credible. How the organization intends to fulfil its commitment to safety is described in a supporting statement of safety policy. This needs to set out an effective safety management framework for the organization to support high standards of safety and to ensure that legal and regulatory requirements are satisfied. The various arrangements comprising the safety management system need to form a coherent and integrated framework for the management of safety. To be effective, the safety policy requires the ownership and active support of senior managers, who should also be involved in disseminating the policy throughout the organization. It is also important that everyone in the organization understand the policy and be aware of his or her role in ensuring safety.

21. The organization needs to develop safety standards that define expectations for the arrangements that are significant to the implementation of the safety policy, e.g. the planning and control of work, the assurance of staff competence and the control of plant status and plant modifications. These define what needs to be done, to what standard and by whom. They should embrace international standards, codes and best practices established by the IAEA and other relevant organizations[2]. Plant vendors and research institutes also have a role to play in establishing appropriate standards and best practices. Safety standards need to be communicated clearly to ensure they are understood by all those involved in their implementation.

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[2] The term 'standard' is used in this report to mean fundamental principles, criteria, requirements and guidance on safety, which are expected to be applied or followed. The term does not encompass codes and other technical documents with engineering specifications, which are usually issued by professional organizations.

22. It is important that adequate resources be made available to implement the safety policy. This includes the provision of safe operating plant, the necessary tools and equipment, and sufficient competent staff (supplemented as necessary by consultants or contractors, including plant vendors). In particular, sufficient resources need to be available to carry out activities in a safe manner, avoiding undue physical or mental stress on individuals.

23. The operating organization needs to demonstrate a commitment to achieving improvements in safety wherever it is reasonably practicable to do so as part of a continuing commitment to the achievement of excellence. The organization's improvement strategy for achieving higher safety performance and for more efficient ways to achieve existing standards will have the best chance of success if it is set out as part of a well defined programme with clear objectives and targets against which to monitor progress.

3.3.2. Management structures, responsibilities and accountabilities

24. *The management structures, responsibilities and accountabilities for safety are clearly defined throughout the organization and in supporting organizations.*

25. Line managers are responsible for the safety of all operations under their control. The structure of the organization thus needs to reflect this accountability of line management for safety. However, the exact management structure will also need to reflect the specific requirements of the organization. It is also important that the roles, responsibilities and authority of managers and management units within the organization be clearly specified and compatible with each other.

26. In assigning responsibilities and accountabilities, it is important that managers ensure that the individuals concerned have the capability and the appropriate resources to discharge these responsibilities effectively. They should also ensure that staff are aware of and accept their safety responsibilities. Staff should also know how their responsibilities relate to those of others in the organization.

27. The role and responsibilities of external supporting organizations (e.g. external maintenance organizations, plant vendors, research institutes and technical support organizations) also need to be clearly defined and understood. Utilities vary in the extent to which they use supporting organizations. Where these supporting organizations play a significant role, the safety management system for the utility needs to embrace their activities, whilst at the same time ensuring that overall control and responsibility for safety rests with the licensee. For example, staff in the utility required to supervise contractors or other support staff should be clearly identified. They should be properly trained for this role and adequately qualified to understand

the work being done by the supporting organization to the extent required to identify and remedy safety concerns should they arise.

28. Particular attention also needs to be paid to maintaining the adequacy of arrangements during periods of organizational change (e.g. arising from deregulation of the electricity supply market). It is important that any proposed organizational changes be clearly defined and their implications assessed and understood by the organization and, to the extent necessary, by the relevant regulatory organization. Staff need to be made aware of how their responsibilities will change both during and after the changes. Consideration also needs to be given to the possible requirement for additional resources to cope with the extra workload that may arise during the transition phase. The issues associated with managing organizational change are discussed in greater detail in Section 4.2.

3.4. PLANNING, CONTROL AND SUPPORT

29. *Planning and control of work is effective and support is given to those undertaking tasks so as to ensure that activities are carried out safely and effectively.*

3.4.1. Planning (including risk assessment)

30. *Safety related activities are properly planned and the risks to health and safety are identified.*

31. Safety related activities need to be properly planned to ensure that they can be carried out safely and effectively. In the case of operational and maintenance tasks, this will involve the use of a work management system to ensure that such tasks are identified, prioritized and correctly executed. Proposed changes to plant or processes also need to be properly planned. In particular, the planning process needs to ensure that the safety significance of any changes are assessed in advance with the level of assessment based on the safety significance of the changes.

32. Suitable and sufficient assessments of the risks to health and safety arising from particular activities need to be carried out. The nature of the required risk assessment will depend on the extent of the risks involved and may be qualitative or quantitative in nature. The purpose of the risk assessment is to identify the acceptability of the proposed activity and the appropriate control measures required to ensure that risks are as low as is reasonably achievable. The results of risk assessment need to be incorporated into work instructions or control documentation associated with the activity, for example in the documentation for the permit to work system.

33. Risk assessment techniques can also contribute to determining maintenance and inspection requirements. In particular, risk assessment can be used to determine the most appropriate surveillance test intervals, the optimal time between equipment overhauls and the appropriate rules governing the release of safety related equipment for maintenance.

3.4.2. Control of safety related activities

34. *Work is properly controlled and authorized. The degree of control depends on the safety significance of the task.*

35. The organization needs to put in place appropriate arrangements to ensure that safety related activities are adequately controlled to minimize the risks to health and safety. The level of control should depend on the safety significance of the task. Activities with a high level of safety significance may require a specially authorized person to carry out the task, such as the reactor operator. In addition, certain critical activities such as tests and experiments will need to be authorized in advance and will involve the use of a permit to work system. Other control measures may include use of hold points and verification stages during complex tasks and the control of stores items and test equipment.

36. All activities that could have a significant impact on safety will be carried out in accordance with written procedures. These define how the activity can be carried out safely and, where appropriate, identify the steps to be taken in the event of an abnormal situation arising. The procedures should be issued and controlled in accordance with the organization's quality assurance programme.

37. Arrangements should be in place to cater for situations that fall outside normal operating or fault procedures, e.g. abnormal findings from inspections and special tests. These arrangements ensure that appropriate control is maintained and due consideration is given to the safety implications of the situation. There also need to be arrangements to deal with emergencies. These cover on-site and off-site responses, including the timely notification to appropriate government, regulatory and support organizations.

3.4.3. Ensuring competence

38. *Staff have the competence to carry out their tasks safely and effectively.*

39. The organization needs to develop appropriate arrangements for the selection and placement of employees. This should ensure that they have the necessary

education, and have the necessary mental and physical abilities for their jobs, or can acquire these through training and experience.

40. A system is required to identify the training needs of all staff following their recruitment. These training needs should be reviewed and revised to take account of organizational changes and changes in plant and processes. Techniques such as training needs analysis are valuable in defining the requirements for technical skills, personal skills (e.g. communication and team working) and management skills.

41. It is important that training provide staff and, where necessary, contractors with an appropriate understanding of the safety case or report[3] for the site, as well as regulatory and corporate requirements. In addition, staff need to obtain an appropriate understanding of the arrangements for the management of safety, for example procedures for the control of plant status and plant modifications. It is also important that individuals gain a wider understanding of the tasks they undertake in order to understand the implications of their activities for others and an appreciation of the importance of issues such as configuration management. Managers and supervisors also require appropriate training. This should include the acquisition of sufficient technical understanding to discharge their role as well as the necessary managerial skills.

42. Training should be provided to an agreed programme and recorded. As part of the training programme, an assessment of technical competence should be made. For particular posts, this may require staff to undergo formal qualification and authorization. Arrangements should be in place for the routine assessment of staff performance in order to identify further training needs and to satisfy requirements for routine retraining and requalification.

3.4.4. Communication and team support

43. *Effective communication and team support allow individuals to receive the advice, information and support they require, and allow them to provide the necessary feedback to others in the organization.*

44. Effective communication systems are essential if policy and safety arrangements are to be understood and consistently implemented. There needs to be good open communication about safety throughout the organization. It is essential that

[3] Safety case or report is used to mean the document or documents that justify the adequacy of the design and proposed operations of the nuclear power plant (see Ref. [1]).

individuals understand and accept why particular standards of safety are required. Communication systems can be both formal or informal depending on the importance of the information provided. They can also be used to reinforce team working through using, for example, team briefings. Communication between shifts is particularly important during both normal operation and maintenance outages.

45. There will be arrangements in place to promote feedback from individuals on safety concerns. These could include both formal mechanisms such as safety meetings and informal mechanisms such as feedback to line managers. It is important that the organization be open and responsive to feedback received from individuals to avoid inhibiting effective communication. Senior managers should also be seen to take an active role in these feedback mechanisms since this demonstrates their interest in receiving the views and ideas of staff.

46. Good teamwork within the organization should be promoted and encouraged. Constructive labour–management relations are an important prerequisite to establishing good working relations between different work groups and between managers and their staff. In addition, the peer pressure generated within teams provides a means to foster and reinforce good work practices. Team members can also provide mutual advice and support. Furthermore, the use of team working assists in the assimilation of new personnel into the culture of the organization.

47. In addition to good communications within the organization, it is important to establish good communications with outside organizations. In particular, there should be well defined and open routes of communication with regulatory bodies. Outside communication should also recognize the broader social framework in which the organization operates, including the maintenance of a constructive dialogue with trade unions and other groups affected by the activities of the operating organization and their representatives.

3.4.5. Supervision

48. *Line managers and supervisors promote and support good safety practices and correct poor practices.*

49. The actions of line managers and supervisors or team leaders have a strong influence on the safety culture within the organization. They will promote safe working practices and will correct poor practices. To achieve this, line managers and supervisors maintain a presence in the workplace through, for example, plant safety tours and the periodic observation of tasks with particular safety significance. It is important for line managers and supervisors to talk to staff on these workplace visits

and communicate their expectations. It is also important that contractors adopt the same high standards of safety achieved by employees of the organization. Line managers and supervisors will encourage and welcome the reporting of potential safety concerns and ‘near misses’ by staff, and are seen to be responding to valid concerns promptly and in a positive manner.

50. Strategies to promote and disseminate good practices and to correct poor practices will be adopted. These will involve the balanced use of appropriate incentives and sanctions. To be effective, it is important that these strategies be well understood and applied consistently and fairly throughout the organization. The most effective strategies for any organization will be largely determined by its existing culture.

3.5. IMPLEMENTATION

51. *The effectiveness of the safety management system is vitally dependent on the contribution of individuals responding to and benefiting from the system.*

52. It is the response of the whole organization that governs the effectiveness of the safety management system. This response reflects the shared attitudes and behaviour of those in the organization and this forms the basis of safety culture. This is a vital aspect, which was extensively covered in 75-INSAG-4 [2]. Therefore, this issue is not discussed further in this report, other than to highlight the desired response of individuals in organizations with a good safety culture, as suggested in 75-INSAG-4:

- — a questioning attitude;
- — a rigorous and prudent approach;
- — communication.

3.6. AUDIT, REVIEW AND FEEDBACK

53. *Audit and review systems provide feedback on safety performance, in order to provide the organization with assurance that its safety policy is being implemented effectively and for it to learn from its experience and that of others to improve safety.*

3.6.1. Monitoring performance

54. *The safety performance of the organization is routinely monitored in order to ensure that safety standards are maintained and improved.*

55. The organization will develop measures to allow its safety performance to be routinely monitored. These measures, taken together, need to have the capacity to highlight whether the safety performance of the organization is deteriorating or being maintained or improved. They should also allow the underlying cause of any deficiency in performance to be identified. This is essential if appropriate corrective measures are to be identified. Their use can also provide a demonstration of the commitment of the organization to continuous improvement. They should also ensure that managers remain aware of actual operating practices. The measures chosen should comprise both reactive and proactive measures of safety performance and be designed to include the performance of contractors and other supporting organizations.

56. Reactive measures make use of information on past performance to gauge current safety performance. Examples of reactive measures include performance indicators based upon the incidence of safety related events and cases of occupational illness. Other performance indicators include measures of the degradation of safety related systems. In some cases probabilistic risk assessment techniques can provide a useful tool for this purpose. The development of key performance indicators for use by the organization to monitor its performance is discussed further in Section 4.3. The analysis of events to identify their root causes is also an important aspect of performance monitoring as a means of identifying weaknesses in the organization's safety management system. It is important that such operational experience (including good practices) be shared within the organization and externally, to provide lessons and ideas to others. The role of national and international reporting systems, such as the IAEA Incident Reporting System (IRS), are important in this respect.

57. Proactive measures make use of information on the achievement of plans and the compliance with safety standards to assess current safety performance. Examples of such measures include the findings from inspections of premises, plant and equipment by supervisors or managers. Other proactive measures include the use of findings from questionnaire surveys which seek to assess employee attitudes towards health and safety.

3.6.2. Audit and review

58. *Audit and review of the overall safety performance of the organization provide an assessment of the effectiveness of the safety management system and identify opportunities for improvements.*

59. The safety performance of the organization should be subject to periodic audit and review to provide a measure of the overall effectiveness of the safety management system. To cover the full breadth of the safety management system, a range of audit

and feedback mechanisms will be needed, which are carried out either internally or through independent agencies. In the case of large organizations with significant impact on nuclear plant safety, this process should involve independent internal management units with responsibility for the independent surveillance of nuclear safety activities.

60. The type of audits and reviews carried out internally include the following.

- Quality audits and management reviews that provide a measure of the adequacy and effectiveness of the organization's documented safety management system. These cover issues such as the adequacy of and compliance with task procedures.
- Safety management auditing systems that allow the organization's safety management system to be assessed against national or international best practices.
- Reviews of safety culture that allow a judgement to be made about the effectiveness of the safety management system.
- Safety case reviews and routine reviews of system reliability (using, for example, probabilistic risk assessment techniques) that provide the means to assess the adequacy of the safety case for the nuclear power plant. Such reviews should also include, where appropriate, consideration of the safety management system. In addition, such reviews can identify cost beneficial improvements, with factors such as developments in international standards and any potential plant ageing issues taken into account. These issues are discussed in detail in 75-INSAG-3 [1].

61. The need for audits and reviews carried out through independent organizations should be recognized. These include peer reviews carried out by international agencies such as the IAEA (i.e. by Operational Safety Review Teams (OSARTs)), and the World Association of Nuclear Operators (WANO) (i.e. peer reviews)[4] as well as local reviews involving staff drawn from other sites within the operating utility and/or other utilities. These reviews provide the means to provide an independent judgement on the effectiveness of the safety management system and its implementation against external best practices.

[4] There are also a number of other agencies involved in audits and reviews, including the Institute of Nuclear Power Operations (INPO) (i.e. INPO evaluations) and the CANDU Owners Group (COG).

3.6.3. Corrective actions and improvements

62. *Appropriate corrective actions are identified and implemented in response to audit and review findings and objectives for improvements are identified as part of the process of striving for continuous improvement.*

63. There need to be arrangements to ensure that appropriate corrective actions in response to audit and review findings are identified and taken. Progress in taking proposed actions needs to be monitored to ensure that actions are completed within the appropriate time-scales. The completed corrective actions should be reviewed to assess whether they have adequately addressed the issues identified in the audits and reviews.

64. There will be a well defined process to support a commitment to continuous improvement. Such a commitment is an essential feature of an effective safety management system. It provides a clear demonstration of the organization's commitment to safety. However, in the drive for improvement, consideration should be given to the cost effectiveness of possible improvement options. The improvement process should make use of the findings from audits and reviews to identify priorities for improvement. To promote ownership of the process throughout the organization, staff should be involved in generating ideas for improvements. An improvement programme should be drawn up to integrate and co-ordinate the various improvement initiatives and to identify the appropriate priorities and resource requirements.

65. Improvement programmes need to be routinely monitored against specified objectives and supporting targets. Senior managers should be involved in this process to demonstrate their commitment. As part of the monitoring process, targets and time-scales should be reviewed and revised as appropriate.

4. SPECIFIC SAFETY MANAGEMENT ISSUES

4.1. INTRODUCING A SAFETY MANAGEMENT SYSTEM

66. Many organizations will already have the components of an effective safety management system in place. However, in some cases these may not have been explicitly recognized and developed as part of a coherent safety management system with the general components identified in Figs 1 and 2.

67. In the safety management system or in the review or upgrading of systems, the following guidance may provide a useful benchmark against which existing systems can be assessed:

— Existing processes and procedures affecting safety can be identified and assessed against the headings identified in this report (or some comparable alternative classification). This may permit deficiencies to be easily identified.
— In some cases, there may exist more than one process within the organization which seeks to achieve the same objective. This may present an opportunity to reduce duplication or overlap. It may also improve clarity with respect to organizational requirements and systems and encourage the adoption of unified best practices across the organization.
— The process of classifying and documenting existing systems may lead to the identification of areas for improvement in the system. For example, it may be that audit, review and feedback systems are predominantly reactive rather than proactive and the balance between these approaches might therefore be adjusted.
— Where analysis of the current safety management system identifies significant deficiencies in the existing system, it is important to introduce remedial measures on a planned and prioritized basis. A useful first step is to assess which deficiencies or shortfalls present the greatest potential threat to safety and seek to introduce or improve systems in these areas as the top priority, moving to lower priority areas at a later stage.
— The checklist given in the Appendix of this report may be of further use as a prompt in order to assess whether the safety management system contains all the desired components and whether these are effective.
— In documenting the organization's system for safety, it is often helpful to clarify:
  — *who* is responsible for a particular part of the system;
  — *what* is the purpose of the process;
  — *how* the process operates and fits into the overall system.
— The clarity and transparency introduced by a systematic review of the safety management system provides a starting point against which the system can be reviewed and audited in future. The existence of a documented system, with a clear, logical basis that has been benchmarked against best practices elsewhere should provide additional confidence and assurance to the regulatory body that there exists a satisfactory system for managing safety.

68. It is often useful to ensure that there exists a hierarchy of documented requirements as part of an overall quality system. At the 'highest' level in the system there will generally be a statement of corporate safety policy. From this starting point, a

logical progression of requirements can be developed. For example, the policy and goals of the organization can lead to a statement of the processes and responsibilities that exist to achieve the goals. Below this, standards can define management expectations for the safety of particular processes. In turn, these can lead on to instructions or procedures used in day to day operations. It is important that these be seen as useful and relevant by those who use them. Staff involvement in producing and reviewing such a hierarchy of requirements should not only improve understanding of safety, but also improve ‘ownership’, because the relevance of those parts of the safety management system affecting the day to day work of the individual will be seen in its overall context as part of a planned system to ensure and improve safety throughout the organization.

69. In principle, it should be possible for all staff to recognize the existence of an unbroken chain of requirements and organizational processes and responsibilities from the boardroom to the workplace, through a logical and consistent auditable trail. The production of an overview document explaining the overall system to all staff in the organization is often beneficial. This helps to ensure a clearer understanding in all parts of the organization of why various components of the safety management system exist and how they are interrelated.

4.2. MANAGEMENT OF SAFETY DURING ORGANIZATIONAL CHANGE

70. It is widely recognized that systems are required in all organizations which operate potentially hazardous plant to ensure that any engineered changes to the plant are properly considered in safety terms before being implemented. For those operational or engineered changes which have the highest potential for degrading safety if they do not meet intended standards or are not implemented satisfactorily, systems should be in place to ensure that proposed changes are closely and independently scrutinized before changes to the plant take place.

71. In recent years, the need to reduce costs and improve efficiency, combined with changes to the structure of electrical utilities and, in some cases, the change of ownership (e.g. privatization) of industries, has led many companies to consider how they might improve work processes and change organizational structures. This has often resulted in reductions in numbers of staff and changes in responsibilities, personnel and interfaces within the organization and greater use of contractors to carry out work. Such changes can lead to either improvements or reductions in safety, depending to a large degree on how they are planned and introduced.

72. For example, safety can potentially be improved by introducing shorter lines of communication, providing clearer accountabilities and simplifying and reducing organizational interfaces. As a specific example, improved planning and work control can increase the productivity of plant maintenance which, in turn, can lead to a reduced maintenance backlog. This is likely to decrease the number of equipment problems with a beneficial effect in reducing the number of plant events and challenges to safety systems. Better planning and work control also means that control room operations staff, maintenance technicians, system engineers, radiation protection personnel and planners are able better to co-ordinate their activities. This increased team working means that changes to the plant can be carried out more efficiently and effectively, with a potential safety benefit.

73. However, pressures arising from organizational change have the potential, if the changes are inadequately effected, to reduce safety. Three examples serve to exemplify the potential dangers. First, pressure for short refuelling outages can lead to inadequate investigation of equipment condition. This, in turn, can lead to short term repairs which can subsequently result in unscheduled forced outages. Second, unless control systems are in place and care is taken to ensure that standards are maintained, a substantial increase in use of contractors can potentially compromise safety. A third example arises when, in attempting to work more effectively under economic and time pressures, workers fail to comply with safety rules or procedures in a misguided attempt to assist the organization to reduce costs. It is vital that management neither encourage such behaviour nor condone it, but make it clear to staff that this is neither intended nor acceptable.

74. Many of the potential adverse effects of organizational change on safety can be avoided if consideration is given to the effects of such change on the maintenance of acceptable levels of safety *before* changes are allowed to take place. By analogy with the processes in place to categorize the safety significance of proposed engineering changes, organizations should establish a system to assess in advance the impact of organizational change, to the extent warranted by its assessed potential safety significance.

75. It is important that, for significant changes, an implementation plan be drawn up which recognizes the need to scrutinize the effects on safety of the proposed changes as they proceed and which recognizes circumstances under which countermeasures might need to be applied should adverse effects on safety become apparent. For such changes, independent internal review may also be required. The regulatory body or bodies will also need to be fully informed about changes with potentially significant effects on safety so that it or they can independently assess the proposed changes, and can inspect and if necessary intervene if they conclude that safety is being jeopardized.

76. For changes where it is judged that potentially significant effects on safety could arise, assessments should ensure the following:

- The final organizational structure needs to be fully acceptable in safety terms. In particular, it is important to ensure that adequate provision has been made to maintain a suitable level of trained and competent staff in all areas critical to safety and that any new systems introduced have been documented with clear and well understood roles, responsibilities and interfaces. All necessary retraining requirements should have been identified by, for example, carrying out a training needs analysis of each of the new roles and planning for retraining of key staff where this has been identified as necessary. These issues are particularly important if personnel from outside the operating organization are to be used for work which has traditionally been carried out internally or if their role is to be otherwise substantially extended.
- The transitional arrangements need to be fully secure in terms of safety. For example, it is important that sufficient existing safety critical expertise be maintained until training programmes are complete and that organizational changes not be made in such a way as to lose clarity about roles, responsibilities and interfaces. Any significant departure from preplanned transitional arrangements should be subject to further review.

77. Organizational change can potentially have broader effects important to maintaining high levels of safety. For example, it is important that the overall strategy for introducing change should recognize the potential for adverse effects on morale and motivation. Changes that are not understood or accepted by the parts of the organization and individuals affected are likely to lead to reduced morale among staff. Good communication and involvement of staff in the change process can often reduce such undesirable consequences. Planning of change that involves staff and their representatives, together with briefing and joint review during the process, is therefore desirable. This may serve not only to improve commitment and ownership, but also to enable new issues to be identified as they arise.

4.3. MONITORING EFFECTIVENESS USING PERFORMANCE MEASURES

78. An important part of the process of audit, feedback and review shown in Fig. 2 is to allow the objective assessment of safety performance within the organization. Therefore, wherever possible and meaningful, measurable indicators of safety performance should be introduced. Monitoring of the measures of safety performance is a management responsibility. While staff can compile the data and develop the reports or summaries, the task of monitoring the results and determining which actions are called for is a vital line management function.

79. The introduction of performance measures enables an organization to set safety targets and to trend performance for the organization as a whole, for individual nuclear power plants and, where feasible, for organizational units within a plant. The inclusion of quantitative performance indicators that are defined nationally or internationally (e.g. those defined by WANO) also allows the organization and individual plants to benchmark their performance against national and international standards. To achieve this it is helpful to adopt indicators, current approaches to which are discussed in the following.

80. There is general agreement that no one indicator has been developed that provides a measure of nuclear safety. A range of indicators needs to be considered in order to provide a general sense of the overall performance of a nuclear plant and its trend over time.

81. These can be measures of recent performance, achievement of actions to improve safety and measures of the attitudes and behaviour of staff. Most conventional quantitative indicators measure historical performance (they are often referred to as 'output' or 'lagging' indicators) and thus their predictive capacity arises from extrapolation of trends or comparisons with past performance. Forward looking indicators (sometimes referred to as 'input' or 'proactive' indicators) which measure positive efforts to improve safety are particularly valuable, although they are recognized as being more difficult to develop and measure objectively. Measures of personnel behaviour and attitudes, although more qualitative in nature, can provide a significant input to judgements about overall safety performance. Although results are usually more difficult to interpret, they have the advantage of providing direct feedback from operational staff and provide opportunities for incipient safety issues to be detected and early signs of deteriorating performance to be identified.

82. In the development of quantitative measures, it is important to recognize potential pitfalls in their interpretation and use:

— Improvement measures usually take a substantial time to be reflected in performance data, particularly when data are analysed on a rolling basis (e.g. monthly data analysed on a 12 month rolling average).
— Care needs to be taken in setting targets and analysing data when dealing with small numbers. Statistical fluctuations can easily mask trends.
— Whenever possible, quantitative measures should not relate solely to failures (e.g. number of events, number of accidents, etc.). Ideally, measures should also be designed to ensure progress on those activities which will improve safety. For example, the reporting of 'near misses', the number of safety inspections and the provision of safety training can all be used as input measures.

- In the development of reporting systems, account needs to be taken of local and cultural aspects that may inhibit reporting, e.g. the response of management to individuals associated with an event, local reward systems based on a reduction in accidents or the number of reported events and a culture which accepts injuries as a part of normal life.
- Numerical measures must always be subject to careful interpretation and be used as part of an overall judgement about safety performance. They should not be regarded as an end in themselves.
- Indicators should be periodically reviewed and their relative importance may change with time. The use of a fixed set of indicators that do not reflect the evolution of the organization and its requirements should be avoided.

83. Many operators of nuclear power plants have developed their own output performance indicators; however, the following 'top level' performance indicators have been used by WANO:

- unit capability factor,
- unplanned capability loss factor,
- unplanned automatic scrams per 7000 hours critical,
- safety system performance,
- thermal performance,
- chemistry index,
- collective dose,
- volume of low level solid radioactive waste produced,
- industrial accident rate,
- fuel reliability.

The extent to which individual indicators in this list are of a direct measure of safety varies considerably, although most of them, at least, provide an indirect measure. Furthermore, it should be recognized that some of these have greater significance for particular reactor types (e.g. the chemistry index) and thus when comparing performance, allowance must also be made for the characteristics of different designs.

84. Experience has shown that plants that have an overall poor record on a majority of these indicators typically have operational problems with a potential impact on safety. As a rule of thumb, when a few of these indicators show declining trends, this can be taken as a useful early warning signal to alert management and to prompt further analysis and investigation of the underlying issues.

85. These indicators are broad based and it is often helpful to monitor other specific or more detailed indicators. For example, analysis of plant events of various types can

provide a useful further input to the assessment of safety performance. The following are among those which might be considered:

- — significant events, measured by both number and consequence;
- — repeat events that have taken place on the plant; these provide a measure of the failure to implement effective corrective actions;
- — events that are similar to those identified at other nuclear plants; in this case, the organization may not have learned sufficiently from the experience of others;
- — events arising from particular types of deficiency (e.g. failure to comply with technical specifications or near misses related to human factors or from deficiencies, in particular in nuclear related systems (e.g. the amount of time a system is declared as not being available — even if within technical specification limits).

86. Where similar root causes recur, a plant probably has weaknesses in its overall performance or cultural deficiencies that are in need of attention. Event analysis has expanded at many plants to include analysis of events without significant consequence (sometimes called ‘near misses’). As it is generally agreed that both consequential and non-consequential events have similar causes, it follows that correcting the causes of non-consequential events should contribute to improvements in safety by helping to prevent future events.

87. It is also sometimes useful to develop detailed indicators for specific organizational units in a plant. For example, in the maintenance area, the following have proved useful for monitoring performance in some organizations:

- — number of outstanding backlogs;
- — a measure of non-proceduralized practices or ‘workarounds’ employed;
- — number of control room instruments out of service;
- — amount of maintenance rework;
- — percentage of spare parts available, as expected, on demand;
- — average life of corrective maintenance actions;
- — a measure of the prevalence of human errors;
- — the completion of training to agreed time-scales;
- — numbers of minor injuries and near misses (an increasing trend in the reporting of these is to be encouraged, since they frequently represent precursors to more serious accidents);
- — standards of housekeeping.

This approach allows, in principle, deteriorating performance in a specific functional area to be recognized at an early stage. Although some of the measures are difficult to define and monitor on a fully consistent basis, they can nonetheless provide an important input to the overall picture and can serve as an added impetus to improvement.

88. There are other more general measures of safety performance that, whilst providing more qualitative information, are an important adjunct to numerical indicators. For example, observations of the behaviour of plant personnel can give an indication of how safely they actually carry out work and comply with procedures and good practices. Observing plant personnel performing work in the field and their interactions with supervisors and managers can provide insight into the safety culture at a plant. Such measures can be supplemented by surveys and interviews into the attitudes of staff. Although these tend to reveal what people think rather than how they act, properly conducted surveys and interviews can provide an accurate impression of the level of safety culture at a plant.

4.4. IDENTIFYING DECLINING SAFETY PERFORMANCE

89. In order to avoid any decline in safety performance, nuclear power plant and utility management must remain vigilant and objectively self-critical. Early signs of declining performance are not readily visible and tend to be ambiguous or hard to interpret. In fact, when the signals are clear, it means that it is often too late and that serious performance problems exist. A key to this is the establishment of an objective internal self-evaluation programme supported by periodic external reviews conducted by experienced industry peers using well established and proven processes. Such a combined programme reduces the dangers of complacency and acts as a counter to any tendency towards self-denial (e.g. ascribing any deteriorating performance to such factors as ‘a run of bad luck’). In addition to the early detection of any deterioration, such an approach can also be used to identify any enhancements of operational performance and safety and to learn from success.

90. Declining performance typically exhibits the following pattern:

Stage 1: *Over-confidence.* This is brought about as a result of good past performance, praise from independent evaluations, and unjustified self-satisfaction.

Stage 2: *Complacency.* In this phase, minor events begin to occur at the plant and insufficient self-assessments are performed to understand their significance singly or in totality. Oversight organizations begin to be weakened and self-satisfaction leads to delay or cancellation of some improvement programmes.

Stage 3: *Denial*. Denial is often visible when the number of minor events increases further and more significant events begin to occur. However, there is a prevailing belief that they are still isolated cases. Negative findings by internal audit organizations or self-assessments tend to be rejected as invalid and the programmes to evaluate root causes are not applied or are weakened. Corrective actions are not systematically carried out and improvement programmes are incomplete or are terminated early.

Stage 4: *Danger*. Danger sets in when a few potential severe events occur but when management and staff tend consistently to reject criticisms coming from internal audits, regulators or other external organizations. The belief develops that the results are biased and that there is unjust criticism of the plant. As a consequence, oversight organizations are often silent and afraid to be the bearers of bad news and/or to confront the management.

Stage 5: *Collapse*. Collapse can be recognized most easily. This is the phase where problems have become clear for all to see and the regulator and other external organizations need to make special diagnostic and augmented evaluations. Management is overwhelmed and usually needs to be replaced. A major and very costly improvement programme usually needs to be implemented.

It is important that declining performance be recognized after the first two stages and at the latest early in Stage 3.

91. The key to a successful internal self-evaluation programme is the establishment of a learning culture throughout the organization with staff at all levels seeking to review their work critically on a routine basis and to identify areas for improvement and means of achieving this. In its turn, management must be supportive, for example by seeking opportunities for both themselves and staff to visit other nuclear power plants to identify good practices that they might adopt. This can occur both on an individual plant to plant exchange basis and also as members of international teams undertaking external reviews at nuclear power plants in other Member States.

92. Specific studies and general experience have shown that frequently occurring underlying conditions at those plants which have had significant problems include:

- — acceptance of low standards of plant condition/housekeeping;
- — failure to recognize that performance is declining and to restore higher levels of performance in specific areas at an early enough stage;
- — a lack of accountability among line management and workers;

— ineffective management monitoring and trending of performance;
— deficient performance in the control room;
— an increasing human error rate;
— inadequate and/or poorly used procedures;
— insufficient and/or ineffective training;
— insufficient use of operational experience feedback and root cause analysis programmes in the analysis of events and ‘near misses’;
— an inadequate control of design configuration;
— failure to benchmark against those with better safety performance;
— a lack of awareness among the top managers about the principal deficiencies and associated corrective actions often reinforced by a ‘good news’ culture;
— inadequate or insufficient self-assessments being carried out on issues relating to safety culture;
— inadequate capability for supervising and monitoring contractors.

93. While weakness in a few areas can exist at even top performing plants, experience has indicated as a rough ‘rule of thumb’ that when weaknesses are apparent in more than a few of these conditions, there is a danger that a significant decline in plant performance is occurring.

94. The routine and objective review of the trends in a set of performance indicators such as those discussed in Section 4.3 is undertaken at most nuclear power plants. An early indication of concern might require the development and monitoring of additional lower level measures of performance to confirm (or otherwise) the existence of a deteriorating trend and to support the identification of the associated root causes. In seeking critically to assess performance, the management at a plant may wish to give particular attention to analysing performance in areas such as those identified in para. 92.

95. Self-assessment has significant advantages as a means to identify such precursors. If it is left to external reviews and audits, or worse still, for actual events to expose these weaknesses, the required corrective actions are often far more extensive and expensive to implement. Early identification and correction at the plant is thus the optimum solution. To achieve this, management must develop within the organization the ability to conduct thorough, critical self-assessments. Also, when areas for improvement have been identified, management needs to establish clearly prioritized action plans that address the root causes, gain ownership for these from staff and pursue them vigorously.

96. Even where self-evaluation programmes have been established, weaknesses can arise for a number of reasons. These include:

- failure to identify the real root causes;
- lack of actual or perceived management commitment in the resolution of the identified problems;
- insufficient attention to the content of remedial action plans and, in particular, a failure to prioritize actions;
- failure to gain the commitment of staff to the changes proposed;
- failure to commit adequate resources to complete the improvement programme satisfactorily;
- insufficient commitment to see the programme through to a stage where actions are complete and have achieved real and measurable improvement.

Appendix

SAFETY MANAGEMENT INDICATORS

In Section 3, the desirable attributes of an effective safety management system were outlined. These attributes should be observable in the way the organization manages safety to ensure high safety standards and a strong safety culture. This appendix comprises sets of questions covering the observable features of an effective safety management system and provides a basis for judging the effectiveness of the system. The list is not exhaustive and could be extended to reflect, for example, the specific safety legislation, regulations and general approaches to safety in a particular country.

DEFINITION OF SAFETY REQUIREMENTS AND ORGANIZATION

Statement of safety policy (including standards, resources and targets)

(1) Is there a safety policy statement that expresses the commitment of the organization to develop an effective system for the management of safety?
(2) Is the policy statement brought to the attention of all staff and reinforced by the active support of senior managers?
(3) Do supporting safety standards provide a comprehensive and integrated framework for the management of safety?
(4) Are resources adequate and are they monitored for adequacy?
(5) Are challenging but realistic safety targets set defining future intentions for continuous improvement?
(6) Does the safety policy take due account of off-site support and the role of contractors?

Management structures, responsibilities and accountabilities

(1) Do the most senior members of the organization have the necessary experience and knowledge to manage the safe operation of a nuclear utility?
(2) Are the roles and responsibilities within the organization clearly defined and understood, with adequate support provided to operations staff from other functions such as maintenance and engineering?
(3) Are the roles and responsibilities of supporting organizations clearly defined and understood within the operating organization?
(4) Is there a process for the management of organizational change to ensure that safety standards are maintained during and after the changes and that the regulatory authorities are kept properly informed?

(5) Are staff adequately informed about changes in responsibility associated with organizational changes?

PLANNING, CONTROL AND SUPPORT

Planning (including risk assessment)

(1) Is there an effective system for identifying and determining the urgency for operational and maintenance tasks?
(2) Are there adequate resources to minimize outstanding plant repairs and maintenance?
(3) Is there an effective system for the planning, assessment and completion of plant or process modifications?
(4) Is there a system for assessing the risks associated with operational and maintenance tasks?
(5) Are the results of risk assessments adequately incorporated into control measures, for example permit to work documentation and task procedures?

Control of safety related activities

(1) Is there a system to identify the level of control required for safety related activities, to ensure that it is not excessive or inadequate?
(2) Is the required level of control consistently provided?
(3) Is there a system to ensure appropriate authorization for safety related activities?
(4) Is there a system to ensure an appropriate degree of verification and supervision for safety related activities?

Ensuring competence

(1) Does the selection process ensure that staff and contractors are suitably qualified and experienced with the necessary mental and physical requirements for the post?
(2) Is there a proper training needs analysis carried out following staff selection or following changes to people's roles or to plant and processes?
(3) Does training provide staff and managers with the appropriate skills and understanding they require for their post, including the implications of their activities on other people, plant or processes?
(4) Is there adequate line management support and resources provided for training, with adequate programmes to develop future managers and team leaders?
(5) Is there an adequate system to monitor individual performance, in order to identify further training needs?

Communication and team support

(1) Is there a broad range of approaches used to communicate with staff (including one to one contact and site-wide communication)?
(2) Are staff and managers adequately informed about the purpose of their activities and the associated safety precautions?
(3) Are there formal mechanisms to allow individuals to provide safety suggestions and raise safety concerns, and is the feedback acted upon?
(4) Is the use of team working adequately supported and promoted?
(5) Does the organization adequately encourage team members to promote and reinforce good work practices within the team and between teams?

Supervision

(1) Is there adequate supervision of staff and are supervisors given sufficient opportunity and encouragement to maintain a visible presence in the workplace?
(2) Are non-employees (such as contractors) sufficiently supervised to ensure they have the same high standards as those in the operating organization?
(3) Are supervisors and line managers given sufficient support and training on effective ways to reinforce good practices?
(4) Do line managers and supervisors encourage and support the reporting of safety concerns by staff?
(5) Are there clearly understood mechanisms in the organization to reward good practices and discourage poor practices?

AUDIT, REVIEW AND FEEDBACK

Measuring performance

(1) Does the organization have a sufficient range of indicators to provide a clear picture of its safety performance, including trends in human performance and equipment failures?
(2) Is the safety performance of the organization regularly compared with that of similar organizations?
(3) Are events investigated in an open and honest manner to allow the underlying causes to be correctly determined?
(4) Is adequate attention given to repeat events and are the results used to review the effectiveness of previous corrective actions?
(5) Are there adequate inspections of the workplace and work practices to assess compliance with the organization's safety standards?

(6) Are indicators identified to monitor the effects of organizational change?

Audit and review

(1) Are the arrangements for the safety management system subject to sufficient auditing to assess their adequacy?
(2) Is the safety case for the plant subject to periodic review and does this review cover the safety management system on site?
(3) Is the site subject to independent peer reviews to gauge the effectiveness of the safety management system and its implementation?
(4) Do the results of audits and reviews lead to visible and effective improvements in the safety management system?
(5) Do senior directors and managers personally monitor the safety performance of the organization and do they have the necessary experience to review critically trends in safety performance?

Corrective action and improvements

(1) Does the feedback from audits and reviews lead to appropriate corrective actions implemented within specified time-scales?
(2) Does the organization implement corrective action prior to adverse comments from other organizations such as regulatory bodies?
(3) Is there an effective process to generate an improvement programme for the safety management system, which makes use of suggestions from staff?
(4) Is the improvement programme adequately resourced and does it have the commitment of senior managers in the organization?
(5) Is progress against the improvement programme routinely monitored and is the programme revised accordingly?

Annex

SOME EXAMPLES OF THE EFFECTS OF DEFICIENCIES IN SAFETY MANAGEMENT

GENERAL CONSIDERATIONS

A–1. From time to time reports on incidents or reviews of a plant or utility serve as a reminder of the continuing need for vigilance and the contribution that all managerial levels play in achieving safe operation. In the first of the two sections below, two examples which illustrate this have been drawn from published major plant/utility reviews. The final section provides specific examples linked to elements of the model presented in Fig. 2 which have been obtained from two IAEA sources — the IRS database and the OSART review findings. They all serve to demonstrate the continuing need to learn from the experience of others in relation to human and organizational issues as well as in technical and engineering areas.

A–2. In focusing on problems, there is a danger of forgetting the many positive successes achieved over 9000 reactor-years of experience accumulated worldwide. The international nuclear community must continue to seek replication of the many excellent practices that have led to these successful achievements as well as learning from well publicized shortfalls. Both can serve as an impetus and as a motivation for change. For those Member States with established nuclear power programmes and systems to support their safe operation, it is frequently factors associated with organization and human behaviour for which significant further improvements can be gained.

RESULTS ARISING FROM THE REVIEW OF NUCLEAR POWER PLANTS

A–3. The 1997 report of a review of a utility and its nuclear power plants identified management, process and equipment problems that had adversely impacted the performance of the organization and its operating stations. Although incidents and poor performance tend to focus attention at the plant operational level, they often arise as a result of weaknesses stemming from the higher organizational level, i.e. those responsible for defining the organization and specifying safety requirements. In this respect the review team found problems with organizational structures, practices, policies and systems.

A–4. These shortcomings inevitably had an adverse impact at the working level of the plants. Specific shortcomings in the planning, control and support activities were found and it was noted that ‘personnel have not incorporated an adequate safety culture into their normal activities’. One vital ingredient in an effective safety management system, namely an effective audit, review and feedback process, was also found not to be working satisfactorily. The utility has made a very positive response to the findings.

A–5. An evaluation (also in 1997) of a nuclear power plant in another Member State by a team from the national regulatory body followed a decline in performance that the regulator had noted and drawn to the attention of the plant a year earlier. Although the robust nature of the plant design, its relative newness and the limited period over which performance had declined were considered to be major factors in preventing significant degradation of plant equipment or an event of more serious consequence, a number of important deficiencies in the safety management system were identified.

A–6. The review concluded that management and leadership were generally ineffective in establishing expectations, communications, independent oversight, performance measurement and monitoring, decision making and human resource management. Programmes, processes and procedures were generally ineffective in self-assessments, corrective actions, root cause analyses, planning prioritization and scheduling. Human performance was found to be weak in procedural adherence, resource allocation and time management and prioritization.

A–7. The root causes of the problems were determined by the team to be:

- — management generally did not establish and implement effective performance standards;
- — the plant’s programmes, processes and procedures did not consistently provide defence in depth to assure plant activities were conducted in a safe manner;
- — problem identification was inconsistent and evaluation and corrective actions were generally ineffective;
- — management did not ensure that the infrastructure was suitable to support the major changes which the management were seeking to implement.

The plant and utility have embarked on a plan to address the issues and their root causes.

A–8. The experiences of both utilities in implementing their recovery programmes provide valuable lessons to the international nuclear community.

WEAKNESSES FOUND FROM REVIEW OF THE IRS DATABASE AND OSART REVIEW REPORTS

A–9. Examples of incidents (as reported to the IRS) and weaknesses in systems that might become the direct or root cause of a future incident (OSART review findings) are provided as a reminder of the need to remain vigilant and to avoid complacency. The latter, in particular, also serves to demonstrate the benefits of periodic external review.

Definition of safety requirements and organization

Statements of safety policy (including standards, resources and targets)

A–10. In an OSART review it was found that many of the rules for the technical specifications of safety equipment surveillance which were in force had been submitted to the safety authorities but had not yet been authorized by them. For example, a programme of diesel generator tests had been submitted to the regulatory authorities by the utility in 1992 but, by the time of the review in 1998, had not yet been approved. A batch of plant modifications had been approved for implementation by the regulator, but not the corresponding changes in specifications for surveillance tests. In those cases where the changes had not been approved, the plant implemented the surveillance proposed to the regulator so that there would be no ambiguity for operators. Some defence in depth was lost because the external review had not taken place. In addition, the use of surveillance tests that had not been approved by the regulator comprised a further loss of defence in depth as a result of a failure to comply with procedural requirements.

Planning, control and support

Control of safety related activities

A–11. During commissioning work on a hot cell in a nuclear power plant, a real spent fuel assembly was disassembled by mistake instead of a dummy fuel assembly. Three members of the maintenance staff received external radiation doses in excess of the dose limit. This event occurred as a result of work being poorly organized. The permit for work did not mention the need for a comprehensive programme of testing and the acceptance testing of the equipment in the disassembly section. Nor was a copy of these programmes attached to the permit, and the members of the team were not informed about it. Nobody in authority had checked that the permit had been correctly drawn up. The permit also made no mention of measures to prepare the workplace (i.e. preparation of the dummy fuel assembly in the hot cell). Therefore the senior mechanical engineer allowed his team to start the work covered by the permit without performing the official procedure for handover of the workplace, including reporting to the works manager. The relevant team began to work under the impression that the hot cell transport apparatus contained a dummy fuel assembly.

A–12. In another example of failures of control, an Assessment of Safety Significant Events Team (ASSET) mission reviewed an incident where during a cold scram test after the refuelling outage, one scram group failed to work. The line-up checks of the valves belonging to that scram group were missed after maintenance had been performed. In addition, a second independent position check of all valves before plant startup also did not detect the wrong system line-up. This event occurred directly as a result of the lack of a rigorous and questioning approach in respect of the maintenance of safety related systems. The root cause was a lack of emphasis by plant management on ensuring adequate control when dealing with safety related systems. There was no planned management or supervisory intervention to verify the stringency of the valve line-up checks. It was noted that management were seldom seen to be visibly endorsing the importance of a rigorous approach when dealing with safety related systems.

Ensuring competence

A–13. In an OSART review in 1997, it was found that material used for training people in the plant was not being systematically reviewed and revised. Most of the existing lecture materials had been developed between 1978 and 1984 and had not been revised to include necessary changes such as plant modifications, operating experience information or procedure changes. The OSART team commented that the use of training notes that are not up to date could result in trainees receiving incorrect information and could lead to mistakes.

Communication and team support

A–14. A reactor startup was terminated and a reactor shutdown was commenced to repair a leaking safety relief valve. The reactor began to depressurize because decay heat was insufficient to supply all auxiliary loads. As the reactor depressurized, the reactor coolant temperature decreased, adding positive reactivity. As long as the operator continued to insert control rods, the reactor was maintained subcritical. The operator stopped inserting control rods to review plant conditions and the reactor scrammed about a minute later. The licensee attributed the event to the control room team failing to recognize the actual plant conditions.

Implementation

A–15. The examples in this category relate to human errors and are thus sometimes simply ascribed to individual failures. However, such issues frequently have their roots in organizational shortcomings which, if addressed, can minimize the extent of such human errors.

Questioning attitude

A–16. During a refuelling outage, one loop was isolated and drained to allow automatic in-service inspection of the steam generator tubes. In parallel, maintenance of the hot and cold leg main isolating valves (MIVs), gearboxes and electrical systems was in progress. One of the maintenance personnel noticed that the position indicator of the MIV wedge did not indicate the fully closed position. As the MIV was not fully secured against movement, he tried to close it. As he could not move the valve in the closed position he turned the wedge by mistake in the open direction. Water was then able to flow from the refuelling/spent fuel pool through the MIV and onto the floor through the open steam generator manhole. The refuelling pool level dropped by approximately 27 cm. Refuelling was stopped immediately and the MIV closed. About 16.6 m^3 of water was lost from the refuelling pool. This incident illustrates a failure to question the safety significance of a course of action when faced with difficult or ambiguous circumstances.

Rigorous and prudent approach

A–17. An OSART review found that the alarm response by reactor operators and radioactive waste control room operators at a plant was deficient. It was noted that several alarms were silenced, then allowed to flash for extended periods of time, including the power range monitor upscales and rod blocks, and alarms on a fire system panel. It was judged that this practice might have arisen because of the large number of alarms. For example, it was noted that over 50 alarms were lit in the radioactive waste control room.

A–18. Alarms are one of the first indications of a problem. Without an adequate response, degradation of plant systems may go undetected. The OSART team recommended that operations management should continuously reinforce expectations to improve operator alarm response. These expectations should include referring to alarm response procedures when an alarm is received, at least for the first time an individual alarm is received on a shift. They recommended that efforts to achieve a 'black board' concept should continue in order to reduce the number of distracting alarms.

Communication

A–19. Poor communication is very frequently an important contributor to incidents. In one example, preparation for refuelling was being performed and the reactor cavity was being filled with water. An examination of the sump area was planned by looking through the access door only. A worker was provided with a key to the sump area and was cautioned not to enter the sump area. The task was delayed until the next shift. The key was passed on but the caution was not. Two workers entered the sump area in spite of the warning on the door. One worker received a dose of 13 mSv (whole body) and the other received a dose of more than 2 mSv.

Audit, review and feedback

Measuring performance

A–20. An ASSET review found that on several occasions the unexpected activation of reactor protection system occurred when the reactor coolant pump was put into operation at 50% reactor power. The reactor power controller repeatedly failed to compensate for the reactivity increase induced by startup of the reactor coolant pump, allowing the neutron flux rate increase to exceed trip settings. This situation occurred on several occasions over a period of time but ineffective performance measuring caused plant management not to take appropriate and timely measures to avoid recurrence. In particular, no thorough analysis verifying the exact cause of the event was performed and no changes to reactor coolant pump procedures or reactor power controller designs response were considered.

A–21. Another ASSET mission found that the inoperability of a diesel generator due to oil cooler leakage was unnecessarily repeated. When the first oil cooler leakage occurred, the plant management decided to replace the tube bundle with one of similar material. A neighbouring power station had, however, previously suffered from an exactly similar problem and had demonstrated that the only solution was to replace the cooler with one of stainless steel. This information had been relayed to the original station but they still replaced the tube bundle with the original material and this again failed after a short time in operation.

Corrective actions and improvements

A–22. Several ASSET review have found corrective actions not being implemented in a timely manner, leading to numerous repeat events. The plants often have excellent computerized systems to store event databases and to analyse events systematically. However, the analysis of failures is often focused mainly on the direct cause and often only a specific area of the root cause is identified for correction. The specific corrective actions to eliminate the individual problem are implemented, but the broader generic lessons remained uncorrected.

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