INSAG-14

Safe Management of the Operating Lifetimes of Nuclear Power Plants

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A REPORT BY THE
INTERNATIONAL NUCLEAR SAFETY ADVISORY GROUP

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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
International Nuclear Safety Advisory Group

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.

The present report by INSAG deals with a general approach to the safe management of the operating lifetimes of nuclear power plants. It responds to the concerns about maintaining adequate safety levels at ageing plants, even beyond their design lifetimes.

Maintaining adequate safety levels implies first and foremost stringent control of equipment ageing, consistent with the design safety bases of the plants. However, as stated in the 75-INSAG-3 report, 'Basic Safety Principles for Nuclear Power Plants', nuclear safety requires a continuing quest for excellence; this implies enhancing the safety levels of operating nuclear power plants as far as reasonably practicable, with due account taken of experience and advancement in knowledge. Moreover, in view of the present situation of the nuclear industry, it may become difficult to maintain adequate competences in many countries with nuclear power programmes.

These topics are considered in this latest INSAG report. I am pleased to have received this report and am happy to release it to a wider audience.

CONTENTS

1. INTRODUCTION

1. The situation of nuclear energy in the world has changed significantly over the past ten to twenty years. In the 1970s and 1980s, many new nuclear power plants were built and commissioned to meet the growth in energy demand. The capacities of these new plants were higher and their economic performance better than those of earlier plants. In this situation, decisions to close older installations were rather easily taken, in view of their technical obsolescence and relatively poor economic performance. Many of the earlier plants were not operated beyond 20 or 25 years.

2. Today, in some countries with increasing electricity consumption, there are still construction programmes for nuclear power plants. However, in many countries where there are plants that were built during the 1970s and 1980s, electricity consumption is growing only slowly and there is no urgent need to embark on the construction of new power plants, whether nuclear or non-nuclear, on a large scale. Other countries are experiencing adverse economic conditions and, even if an increase in their electricity generating capacity were desirable, the large investments required to build new nuclear power plants are not possible, and there are even difficulties in maintaining an adequate safety level at existing nuclear power plants.

3. At the same time, energy markets are generally becoming more open and competitive. Under these circumstances, operating organizations, and notably those operating nuclear power plants, find it particularly attractive to extend the operating lifetimes of their plants at the lowest possible cost. Nuclear power plants that were commissioned during the 1970s and 1980s were generally designed for operating lifetimes of 30–40 years; some operating organizations are now investigating the possibility of extending the operating lifetimes of some plants up to 45, 50 or even 60 years.

4. These considerations call for increased attention to be paid to management of the operating lifetimes of nuclear power plants. In this respect, a crucial issue is the decision about the end of life of a plant. Such a decision would normally be governed by economic considerations, taking into account the technical and regulatory status of the plant and its technically possible and reasonable remaining lifetime. However, it is not independent of previous decisions about ageing issues, upgrading studies and plant modifications. Proper management of the operating lifetimes of nuclear power plants will therefore help to minimize or eliminate avoidable or premature plant shutdowns.

5. As a general principle, a high level of safety has to be achieved at all times for each of these plants, as promoted by 75-INSAG-3, ‘Basic Safety Principles for

Nuclear Power Plants' [1]. It is therefore important that, especially in countries where nuclear power plants provide a significant part of the electricity supply, ageing problems can be anticipated and the need for plant replacement be thoroughly investigated well before acceptable safety conditions can no longer be maintained at an economic cost. The construction of fossil fired power plants takes several years, and it takes even longer for nuclear units. Decisions to order new electricity generating capacity have to be made in a timely manner, with account taken of potential technical difficulties in the design and construction phases and of the need to obtain operating licences. More generally, to avoid any conflict between meeting the demand for electricity production and the safety status of nuclear power plants, challenges relating to ageing have to be dealt with by the operating organizations, the constructors and the regulators so as to maintain effectively at all times a high level of safety.

6. This INSAG report is devoted to providing a general approach to safe management of the operating lifetimes of nuclear power plants. It complements the INSAG-8 report, 'A Common Basis for Judging the Safety of Nuclear Power Plants Built to Earlier Standards' [2], which presented a conceptual approach for dealing with the differences between the safety levels of existing nuclear power plants built to earlier standards and current safety levels. The present report deals with the evolution of the safety of nuclear power plants in relation to their operating environment and history.

7. Although the risks and costs associated with a nuclear power plant do not fall to zero at the end of its operating lifetime, this report deals neither with decommissioning aspects nor with aspects of spent fuel storage and disposal. It is to be recognized, however, that management of the full life cycle of a nuclear power plant includes these aspects and that some structures, systems and components of a nuclear power plant are needed for, or would assist in, maintaining safety beyond the end of its operating lifetime.

8. This report:

— suggests a general safety objective for safe management of the operating lifetimes of nuclear power plants;
— reflects on the ageing processes that can degrade the integrity of structures and components over time;
— presents some considerations about ageing that should be taken into consideration at the design and construction stages for new plants;
— presents principles related to the treatment of physical ageing of structures and components, in order to maintain operating plants consistent with their initial design basis;

— emphasizes the need to check whether the safety levels of operating plants are still acceptable, or whether they may possibly have to be upgraded;
— promotes safety reviews as a good means of dealing with these issues;
— draws attention to infrastructural issues that may influence the capability to provide adequate means for safe management of the operating lifetimes of nuclear power plants, and underlines that these areas have also to be properly managed;
— emphasizes the distinct yet interdependent roles of both the operating organization and the regulator in the safe management of the operating lifetimes of nuclear power plants.

2. GENERAL SAFETY OBJECTIVE

Objective:

9. The general objective for safe management of the operating lifetimes of nuclear power plants is to maintain the safety level of each plant at all times higher than its reference level defined by the corresponding safety case, which is the basis for safe operation and which is at the same time consistent with the regulator's requirements.

10. This general objective covers two issues. Firstly, the characteristics of the various structures and components related to the safety of a nuclear power plant should not degrade below the values considered in the design, which incorporates provisions for ageing effects. Secondly, the expected and acceptable safety level at the time of the design may later come to be regarded as insufficient and its continued acceptability for further operation has to be assessed.

3. AGEING PROCESSES

11. Nuclear power plant ageing can, if not correctly managed, result in the operating safety level falling below the reference safety level set at the design and construction stages of the plant and accepted by the regulator prior to plant operation.

12. The structures and components of a nuclear power plant are subject to physical changes caused by ageing, as are those of any industrial plant. Physical ageing involves changes (often degradation) in the characteristics of structures and components arising from their service or storage conditions; however, the rates of these changes vary considerably. The time dependent degradations can impact significantly on the safety, reliability, operating efficiency and cost effectiveness of industrial facilities. For example, physical ageing, if not adequately controlled, could increase the frequency and magnitude of abnormal events and lead to loss of availability or premature plant closure.

13. It is normal industrial practice therefore to repair, refurbish or replace plant equipment that has failed and, in some cases, plant items the reliability of which has been called into question. Some items are, in fact, replaced in advance of failure on a schedule that takes account of the failure history of the item or similar items.

14. Particular difficulties arise if an item is no longer available, whether because it has been technically superseded or because the supplier no longer exists or no longer manufactures the item. This concerns especially instrumentation and control systems, because of the fast technological development in this field in which digital equipment and computerized systems are progressively taking the place of relay based systems. This new technology is itself changing very fast, so that performing maintenance and ensuring the availability of spare parts for the replacement systems may also turn out to be difficult well before the end of the operating lifetime of the plant.

15. Nuclear power plant practices, which developed from four decades ago when there was no significant operating experience, differ from normal industrial practices in that they are based to a much greater extent on surveillance, monitoring, inspection, testing and engineering evaluation. There is an essential linkage between the operating lifetimes of nuclear power plants, which depend on the evaluation of age related degradation effects and on the determination of the capability to manage those effects, and the surveillance, monitoring, inspection, testing and engineering evaluation activities. This linkage is more than just the demonstration that a particular programme or set of programmes (e.g. in-service inspection) can manage the development of a particular effect (e.g. corrosion and reduction of wall thickness). It requires a comprehensive assessment of all the relevant factors, including the periodicities of the programmes, the rigour of the acceptance criteria, the extent of corrective actions and the exposure of personnel. This assessment ensures that the management of ageing effects through operation and maintenance strategies guarantees that the safety functions of the structures, systems and components will continue to be performed.

16. The operating lifetime of a nuclear power plant is limited for the same reasons as the operating lifetime of any other industrial facility, as a result of the physical ageing of structures and components. However, some features of nuclear power plants set them apart from other industrial facilities. These include:

— degradation mechanisms that are directly linked to the use of nuclear energy; one typical example is the embrittlement of the reactor pressure vessel of a pressurized water reactor due to the neutron flux from the reactor core;
— radiation doses (both individual and collective) that could be received by workers during surveillance activities; access to some equipment is possible only after a sufficient reduction in the dose rates or through the use of equipment specially developed for that purpose;
— potentially high radiation doses that may also preclude the repair or replacement of some plant items owing to the excessive risk to workers; one typical example again is the reactor pressure vessel of a pressurized water reactor.

17. The identification of possible degradation mechanisms takes into account operating experience and the results of research. It is therefore essential that links among operating organizations are developed and maintained to exchange information on operating experience and to optimize research. However, there are limitations in the quality of the predictions of the effects of degradation mechanisms, notably because the tests cannot always be performed over extended periods of time and because they may not be truly representative of actual plant conditions. There are examples of cracking due to corrosion mechanisms or vibrations which was not predicted but actually occurred in operating nuclear power plants. Particular attention has to be paid when changes are proposed in the operating conditions of a nuclear power plant; for example, a slight increase in operating temperatures can result in a significant acceleration of corrosion phenomena.

18. It is therefore important that comprehensive and systematic studies be conducted over the entire operating lifetimes of the plants in order to:

— enhance or refine understanding of significant ageing mechanisms;
— determine the cause of any failure or unexpected degradation experienced during operation;
— develop existing and new techniques to improve the prospects of timely detection of ageing degradation;
— seek to control the rates of the ageing processes or to mitigate their effects.

4. CONSIDERATIONS RELATED TO DESIGN AND CONSTRUCTION

Principle:

19. Degradation mechanisms that could be detrimental to structures, systems and components related to the safety of a nuclear power plant are taken into account from the design stage. Design provisions are made to permit appropriate surveillance activities throughout the operating lifetime of the plant in order to verify the continued acceptability of operation at an adequate safety level. Consideration is also given to potential future requirements for repair or replacement of structures, systems and components.

20. Structures, systems and components related to the safety of a nuclear power plant are designed so as to permit an adequate reliability to be maintained over its operating lifetime. Reliability can be jeopardized by ageing processes which, if unchecked, may lead to reduced safety levels. These processes are therefore considered from the design stage and provisions are made to limit to an acceptable level the effects of any degradation mechanism on the safety of the plant; this includes the specification of service conditions for structures, systems and components.

21. Particular attention is paid to the reliability of equipment which is required to perform a safety function under accident conditions. Such equipment is qualified taking into account not only the potential ambient accident conditions but also ageing effects. Qualification has to be maintained throughout the operating lifetime of the plant and can give rise to the need for periodic replacement of equipment.

22. Recognition is also given to the potential increase in the probability of common cause failures due to the degradation of redundant components. Consideration of ageing processes may therefore lead to the introduction of diversity into the design to ensure that an adequate level of reliability can be maintained.

23. Where practicable, the design incorporates arrangements for monitoring, examination, inspection and testing of structures, systems and components related to the safety of the plant, to confirm that their functional capability is maintained during its operating lifetime. If the arrangements incorporated in the design do not enable monitoring, examination, inspection and testing activities to be performed that are commensurate with the safety importance of structures, systems and components, alternative means are provided to compensate for potential unrevealed failures.

24. Consideration is also given at the design stage to minimizing the time, trouble, cost and physical difficulty of surveillance activities and maintenance, including repair or replacement, which may be necessary to preserve the functional capability of the plant. Such an approach has the potential to reduce not only the costs of plant operation but also, more importantly, the doses to the workers involved.

25. Ageing of structures, systems and components begins with the construction stage. Mistakes or oversights at this stage in equipment related to the safety of a plant can induce life limiting consequences for the plant. Therefore, work management and surveillance activities at the construction stage are undertaken with great care.

26. Important considerations during the construction stage are :

— avoiding inappropriate working methods;
— undertaking careful review of proposed design changes;
— providing adequate quality assurance levels at the plant site;
— controlling the environment for equipment, especially for sites near the sea coast.

5. COMPARISON WITH THE DESIGN BASIS

5.1. MAINTAINING THE DESIGN SAFETY LEVEL OF THE PLANT

Principle:

27. In order to meet the general objective for safe management of the operating lifetimes of nuclear power plants, adequate provision is made to confirm that the characteristics of the various structures, systems and components related to the safety of each plant remain better than the limiting characteristics considered at the design stage.

28. The equipment of a nuclear power plant ages as does that of any industrial plant. Physical ageing involves time related changes in equipment due to its service or environmental conditions, and may degrade characteristics below the levels considered in the safety case, which is elaborated at the design stage and which is at the same kind consistent with the regulator’s requirements.

29. The effective application of this principle implies that:

— the limiting functional characteristics of the various items of equipment related to the safety of the plant are defined and reviewed;

— the degradation mechanisms for these items of equipment are identified and provisions such as adequate operating procedures and technical specifications are implemented to minimize the expected degradations; the effects of ageing are monitored and the results are used to predict the residual potential lifetime of the plant;
— a maintenance policy is in place, so that appropriate decisions are taken in a timely manner to maintain the safety characteristics within allowable ranges, by repair, replacement or adjustment of operating conditions.

5.2. MONITORING THE EFFECTS OF AGEING

Principle:

30. Surveillance activities such as monitoring, examination, inspection and testing are conducted to detect abnormal evolutions of the characteristics or condition of the various structures, systems and components related to the safety of the plant, commensurate with the safety importance of the equipment.

31. Some detrimental effects of degradation mechanisms can be detected from changes in the performance characteristics or condition of structures, systems and components. For many degradation mechanisms that are gradual, appropriate monitoring can provide adequate time to predict the rate of degradation and to implement corrective actions, as necessary.

32. The scope and the frequency of surveillance activities depend on the safety importance of the corresponding structures, systems and components as well as on the knowledge of degradation mechanisms. For example, the scope of in-service inspections of passive components includes critical welds and high stressed regions such as nozzle corners, reducers and bends. For the structures, systems and components important to safety, surveillance activities are implemented even when the possible effects of known degradation mechanisms are calculated to occur much later or not to lead to failure. Experience has shown that such surveillance activities are important, for example in the case of corrosion.

33. More generally, surveillance activities correspond to the second level of defence in depth as defined in the 75-INSAG-3 and INSAG-10 reports [1, 3]. These activities are essential to reveal at an early stage previously unknown degradation mechanisms or unexpected levels of degradation. They can be enhanced or modified during the operating lifetime of a nuclear power plant, depending on advancements in knowledge, in connection notably with operating experience and the results of

research. As an example, thermal stratification has been observed in several instances in piping systems of nuclear power plants. Where thermal stratification has not been taken into account at the design stage, the phenomenon can lead to additional stresses which accelerate the ageing processes in the piping systems affected. It was therefore necessary to perform extensive measurements to determine the real loads on such pipes and to assess their residual operating lifetimes, so that timely decisions on replacement could be taken.

34. The actual evolution of equipment may differ considerably from the expectations at the time of the design, with either beneficial or harmful effects on safety. Adequate predictive modelling requires accurate input data pertaining to material and environment related parameters which have a bearing on the nature and the kinetics of the relevant degradation mechanisms; this applies, for example, to the thermal stratification mentioned above. To obtain data, taking samples from equipment in operating nuclear power plants at different ages may be beneficial.

35. The surveillance activities, as well as the repair and replacement works, can imply the use of specific devices developed to facilitate these activities and works and to reduce, as far as possible, the associated doses to workers. Moreover, today, the implementation of large scale inspection programmes to identify unexpected degradation, or to determine the evolution of degradation, could be limited by the capabilities of the available techniques, notably of non-destructive examination techniques. This calls for the implementation of research programmes and development activities relating to diagnostic techniques to improve the ability to assess the real condition of ageing nuclear power plants.

5.3. LIFE LIMITING EQUIPMENT

Principle:

36. The list of the equipment of a nuclear power plant that may technically limit its operating lifetime is established and reviewed periodically. These plant items are subject to specific surveillance and to periodic reassessment of their residual operating lifetimes, account being taken of existing operating experience and improvements in knowledge of degradation mechanisms.

37. The benefit of a good ageing management programme is that the operating lifetime of a nuclear power plant would in practice be limited only by the degradation of:

— items that could not be realistically replaced because of the technical complexity of the replacement and of the associated cost (e.g. reactor pressure vessel, containment building, large parts of electrical, instrumentation and control cables);
— items that could not be economically replaced after ‘failure’, owing to the limited expected residual operating lifetime of the plant (e.g. steam generators that would ‘fail’ a few years before the end of the expected operating lifetime of the reactor pressure vessel).

38. However, the operating lifetime of a nuclear power plant might also be limited by the fact that too many components would need to be replaced at the same time, or in a short period of time, owing to their states of degradation. The decision of an operating company to limit the operating lifetime of a specific plant, or of a generation of plants, could be the result of an overall view of the condition of a whole range of structures, systems and components.

39. The potential operating lifetimes for components considered not to be replaceable are assessed and periodically updated, enabling a prediction of the plant’s potential operating lifetime to be made. In parallel, the remaining potential operating lifetimes of the major items that could be replaced are also assessed and periodically updated, enabling decisions to be made on whether and when major repairs or replacement have to be made. Checks are also made to confirm that not too many components would have to be replaced over a short period of time, thus creating a further possible limit to future economic operation.

5.4. ASSESSMENT OF THE SURVEILLANCE RESULTS

Principle:

40. The surveillance results are fully assessed. When these results show that the actual behaviour of an item related to the safety of a plant is worse than expected, the necessary corrective actions are taken in due time, depending on the safety importance of the plant item; these actions include, as appropriate, modifications to the operating conditions of the plant, increased monitoring, more frequent testing, and immediate or early replacement of the plant item. Moreover, corrective actions are considered for other similar items, including items at other plants.

41. The results of surveillance activities are helpful to improve the predictive models used to understand the possible effects of ageing mechanisms; they can reveal deficiencies in these models, requiring more data or a better understanding of the prevailing mechanisms.

42. The data collected are effectively used to estimate the future conditions of the structures, systems and components related to the safety of the plant and to form a basis for sound decisions concerning the plant operating lifetime.

5.5. ANTICIPATION OF POSSIBLE REPAIR OR REPLACEMENT WORK

Principle:

43. Programmes related to possible repair or replacement work are defined well in advance, so that they can be implemented in a planned and systematic manner (ensuring, for example, the development of adequate specific tools and ALARA approaches in due time). This is particularly important to deal with degradation that could affect simultaneously a significant part of the means of energy production of a country.

44. The structures, systems and components related to the safety of a nuclear power plant contain routinely replaceable items, as well as items that it would be difficult and/or costly to repair or to replace; there may also be difficulties associated with radiation or contamination levels in areas where repair or replacement works are to be planned.

45. It is therefore useful to identify as early as possible when repair or replacement work could be needed, in order to plan the work programmes soon enough not to jeopardize either the timely completion or the quality of the work, or, indeed, the associated costs. Long delays or unnecessary costs could adversely influence decisions about the future operating lifetime of a plant.

6. REVIEW OF THE REFERENCE SAFETY LEVELS

6.1. PLANT REFERENCE SAFETY LEVELS

Principle:

46. The reference safety level of a nuclear power plant is improved as far as reasonably practicable throughout its operating lifetime, taking into account advancements in knowledge, notably through the feedback of operating experience, and the safety levels of newer plants.

47. In Section 2 of this report, a general objective relating to safe management of the operating lifetimes of nuclear power plants is stated; it indicates that the safety level of each plant is maintained at all times higher than its reference level defined by the corresponding safety case, which is the basis for safe operation and which at the same time is consistent with the regulator's requirements. The initial reference safety level of a plant is the design safety level of this plant, as it is accepted by the regulator, prior to operation.

48. Here it is emphasized that, where reasonably practicable, this reference safety level is improved over time. The rationale is that the expected operating lifetime of a nuclear power plant covers decades; what was once considered an acceptable safety level may be judged insufficient 30, 20 or even 10 years later.

49. As an example, concerning the severe core damage frequency (which may be considered one indicator of the safety level of a plant), the 75-INSAG-3 report [1], published in 1988, states that "*The target for existing nuclear power plants consistent with the technical safety objective is a likelihood of occurrence of severe core damage that is below about* 10^{-4} *per plant operating year. Implementation of all safety principles at future plants should lead to the achievement of an improved goal of not more than about* 10^{-5} *such events per plant operating year. Severe accident management and mitigation measures should reduce by a factor of at least ten the probability of large off-site releases requiring short term off-site response.*"

50. Similar considerations apply to the extent of implementation of the defence in depth concept to different generations of plants, with respect to, for instance:

— the scope of internal initiating events considered at the design stage;
— the scope of the external events considered at the design stage (including seismic design);
— the performance of instrumentation and control systems;
— the reliability of safety systems (including redundancy, prevention of common mode failures and functional back up).

51. Improvements to the actual safety level of a plant are obtained either through improvements to its overall quality of operation or through upgrades of the safety requirements applicable to the plant; in this respect, particular consideration is given to the results of probabilistic safety assessments to complement, as appropriate, deterministic design rules. It is therefore worthwhile to compare the current safety requirements applicable to the plant with the safety requirements applicable to the most recent plants, in order to decide if the current safety requirements are still sufficient and acceptable.

52. For this purpose, it is advisable to identify as clearly as possible and to record the current safety requirements applicable to the plant and how they have evolved since the design stage. This record establishes the reference safety level for the plant.

53. In general, however, an old installation will not meet all the safety requirements set for a new plant, although compensatory measures may sometimes be implemented to obtain a similar safety level, or at least a safety level improved over the design safety level. For example, in some countries, specific measures have been implemented in operating plants with regard to the prevention of core melting for situations that were not taken into account at the design stage (such as the total loss of normal and emergency power supplies or the total loss of heat sink). Accident management provisions are also implemented in existing plants in order to reduce radioactive releases to the environment in the unlikely event of a core melt.

6.2. REASONABLY PRACTICABLE UPGRADES IN THE REFERENCE SAFETY LEVELS

Principle:

54. While improvements are to be sought, upgrades to the reference safety level of a plant are actually decided only where they are reasonably practicable, i.e. where the effective overall safety benefits outweigh the likely loss of operating time, the costs and the physical difficulty of achieving the corresponding modifications.

55. It is not possible to give a general definition of what is reasonably practicable. Conclusions on which upgrades are actually implemented generally result from a discussion process involving both the operating organization and the regulator. This discussion process is based on safety cases including, as far as necessary, deterministic and probabilistic studies as well as cost–benefit analyses.

6.3. STABILITY OF THE REFERENCE SAFETY LEVELS

Principle:

56. Upgrades in the reference safety levels, with the associated revision of applicable rules and standards and the implementation of plant modifications, are preferably achieved by steps.

57. The safety of a nuclear power plant relies not only on structures, systems and components (which may have been upgraded since the design stage), but also on how the operator complies with the equipment requirements during routine operation and maintenance. Frequent changes or accumulation of changes, whether related to plant modifications, procedures or organization, introduce a degree of uncertainty in the minds of the operators and do not facilitate ‘ownership’ or compliance with current rules and procedures. On the contrary, the stability of the plant configuration (including its reference safety level) for a reasonable period of time facilitates compliance to current safety procedures and practices and the verification of such compliance, and therefore contributes to the overall achievement of a good safety performance.

58. A good practice is to address the evolution of safety levels for operating nuclear power plants via safety reviews. The approach to such reviews is discussed in the following.

59. In contrast to the correction of deficiencies in comparison with the current reference safety level, the modifications to be implemented in a plant or in its procedures following an upgrade of its reference safety level do not have the same degree of urgency: what is considered as an acceptable safety level at a given time does not become unacceptable overnight.

60. The implementation of the subsequent hardware or procedural upgrades, therefore, is preferably undertaken with due care and with time for detailed planning and preparation. A consistent approach to upgrades facilitates their implementation as well as training of the operators and updating of the documentation. Furthermore, when upgrades are applicable to a series of identical or similar plants, they are staggered over a certain period of time, account being taken of the ages of the plants and the interest in avoiding implementation at all the plants at the same time.

7. SAFETY REVIEWS

Principle:

61. Safety reviews are undertaken to provide an overall view of the actual safety status of a nuclear power plant. They include a determination of whether its ageing is being effectively managed as well as a discussion on the possible evolution of its reference safety level.

62. Safety reviews of the overall technical status of each individual plant, which look forward over a sufficiently long period of potential future operation of this plant (for example ten years), are undertaken to provide confidence that it would be technically feasible to operate the plant in consistency with the applicable safety requirements during the further operating period. Safety reviews take into account the reference safety levels for newer plants as well as the developments in technology and advancements in underlying scientific knowledge and analytical techniques.

63. Safety reviews provide important inputs into the decisions of the operating organizations on the further operating times of the plants and on the investments that they are prepared to make to secure those operating times.

64. More precisely, safety reviews normally include the following elements which relate directly to safe management of the operating lifetimes of nuclear power plants:

— documentation and review of the current reference safety level, which includes any changes related to safety implemented during the plant operating period to date;
— verification that the plant structures, systems and components as well as its operating procedures and operational safety performance are consistent with its current reference safety level;
— identification and prioritization of any reasonably practicable modifications to the plant or to its operating procedures to improve its reference safety level, with due recognition of the fact that modifications to operating plants are likely to be more costly than those to new plants at the design or construction stage. Moreover, plant modifications are generally much more costly than procedural modifications.

65. During the safety review process, information is examined both from the plant itself and from similar plants. For the plant under consideration, the safety review takes into account the actual characteristics of the individual plant and its operating history. Documentation relating to the particular design features of the structures, systems and components of each plant is maintained throughout its operating lifetime, as well as records about transient cycles, anomalies, incidents or accidents that have occurred during its construction and operation.

66. One possible outcome of a safety review is that reasonably practicable modifications can be achieved without recourse to any operating restrictions; such modifications can form part of a modernization programme that is implemented at a family of plants. In this case, a phased implementation programme is carried out in a planned and systematic manner. Another outcome could be that plant operating conditions and procedures have to be changed; the impact of such changes on operator training has then to be considered.

67. Ultimately, a position could be reached where it would be uneconomic to modify the plant or its operating procedures to be able to demonstrate that it could be operated safely beyond a specific date; this effectively determines the potential end of the operating lifetime of the plant.

68. It is possible that difficulties arise where new data or methods are required to be introduced into the safety analysis. Such situations, for example with regard to earthquakes, are discussed on a case by case basis with the regulator, depending on the evolution of the data or of the methods, as well as on the proposed potential operating lifetime of the plant and on the reasonably practicable plant modifications. However, the result may be that an adequate safety level cannot be demonstrated, even if reasonably practicable plant modifications were to be implemented.

8. INFRASTRUCTURE SUPPORT FOR SAFE MANAGEMENT OF THE OPERATING LIFETIMES

8.1. MAINTAINING ADEQUATE COMPETENCE

Principle:

69. Sufficient staff with adequate competences in all fields related to the safety of nuclear power plants are maintained during the whole operating lifetimes of these installations. This implies not only the recruitment of operation and maintenance personnel who are given appropriate training and retraining, as necessary, but also the maintenance of an in-depth knowledge of the plants, which is normally provided by the designers and constructors, and the capability to undertake appropriate research activities.

70. The considerations referred to above about the physical ageing of operating nuclear power plants are generally well understood. However, the safe operation of a nuclear power plant over its entire lifetime relies not only on maintaining or upgrading structures, systems and components related to its safety but also on the competence of the personnel within the operating organization, the designers and constructors, and staff in the research and development institutes.

71. On this topic, the 75-INSAG-3 report [1] indicates as a principle that "*engineering and technical support, competent in all disciplines important for safety, is available throughout the lifetime of the plant.*"

"The continuing safe operation of a nuclear power plant requires the support of an engineering organization, which can be called on as required to assist with plant modifications, repairs and special tests, and to provide analytical support as necessary for the safety of the plant. This resource may be provided within the operating organization itself or it may be available from the plant suppliers or specialist groups. It is the responsibility of the operating organization to ensure that the resources required are available."

72. The 75-INSAG-3 report [1] also underlines that *"research and development activities are needed to maintain knowledge and competence within organizations that support or regulate nuclear power plant activities."*

73. Today, this issue is emerging as an important one in some countries, arising from the present situation of nuclear energy in the world. For example, there could soon be a shortage of engineers familiar with neutronics if this discipline is no longer taught because it is not sufficiently attractive to students. To combat this, the operating organizations have to take steps to maintain adequate competences, for example by developing their own engineering services or by developing competences in other organizations.

74. Moreover, maintaining adequate competences in some specialized fields implies sustaining links with research. It would be wrong to think that, since many nuclear power plants have now been operating for more than 20 years without great difficulties, serious challenges to the operating lifetimes of nuclear power plants are not to be expected; appropriate responses to such challenges would require specific competences and possibly research facilities and personnel to be available.

8.2. HANDLING MAJOR ORGANIZATIONAL CHANGES[1]

Principle:

75. As far as possible, major organizational changes are managed in such a way as to avoid any significant impact on the continued safe operation of the nuclear power plants concerned.

[1] This topic is extensively discussed in another INSAG report, 'Management of Operational Safety in Nuclear Power Plants' [4].

76. The operating organization carefully assesses the impact of any major organizational change, whether related to itself or to support from the industry, as far as possible before the decision is made.

77. Nevertheless, in a number of cases, organizational changes occur without the operating organization (or the regulator) being able to influence matters. This can happen, for example, in the case of a failure of a constructor/supplier. Contingency plans are worked out in advance as far as necessary to accommodate changes in the contractual relationships. In any case, after assessment of the consequences of a real change, the operating organization implements appropriate compensatory or alternative measures to secure the capability lost.

78. Major changes include changes in the industrial capability to produce new spare parts or to supply replacement components. The operating organizations therefore look for long term partnerships with contractors and potential alternative suppliers for critical components.

8.3. EXCELLENCE IN OPERATION

Principle:

79. The management of a nuclear power plant strives continuously for operational excellence, making the best use of self-assessments and peer reviews to confirm adequate operational safety performance. Measures for improvements are defined and implemented where necessary.

80. Another possible challenge to the operating lifetime of a nuclear power plant is the degradation of plant safety performance that would result from inadequate management and safety culture. Furthermore, confidence in the ability of an operating organization to manage in a safe manner is largely based on past and present records. Continued excellence in operating performance is therefore a foundation for future safe operation.

81. A self-assessment is used to compare the actual plant safety performance with expectations and to identify any areas requiring improvement. Strong support from the operating organization's management is essential to obtain the best results and to encourage individuals at all levels of the organization to follow this approach.

82. A peer review is conducted by a team of independent experts with technical competence and experience applicable in the areas of the evaluation. The conclusions

of the review are based on the combined expertise of the team. Such a review is not an inspection or an audit against specified standards; instead, it is a comprehensive comparison of practices applied by organizations with existing and internationally accepted good practices and an exchange of expert judgements, aimed at strengthening the effectiveness of the organization being reviewed and of its current practices and procedures. In addition, participation in peer reviews can also be effective as a means to maintain and develop competences for the personnel conducting the review itself.

9. MANAGEMENT RESPONSIBILITIES

Principle:

83. Safe management of the operating lifetime of a nuclear power plant relies on the operating organization's understanding and fulfilment of its ultimate responsibility for the safety of the plant over its operating lifetime. The regulator provides licensing and regulatory control of the plant and enforces the relevant regulations, and retains its independence as a safety authority.

84. The operating organization has the primary responsibility for defining and implementing the ageing management programmes and assessing the results of surveillance activities to confirm that the reference safety level of the plant is actually achieved. The regulator assesses carefully the ageing management activities implemented by the operating organization to satisfy itself with regard to the scope and the content of the overall programmes.

85. Assessment of surveillance results may conclude that some corrective actions are required to ensure that the plant actually achieves its reference safety level. Adequate corrective actions are defined and implemented by the operating organization. The regulator monitors the implementation and takes enforcement actions, where necessary.

86. Regulatory practices vary and, in some countries the licences related to nuclear installations have defined time limitations. In such a case, any extension to the operating licence of a nuclear power plant beyond the defined limit requires the issue of a new licence. This would normally occur after assessment of a safety analysis report by the regulator to verify that an appropriate reference safety level can actually be achieved for a new period of operation. Whatever the regulatory practice, the

overall technical status of a plant is discussed between the operating and regulatory organizations, with due emphasis on those items important to safety.

87. As described in Section 7, the operating organization of a nuclear power plant considers what improvements can reasonably be made to the reference safety level of the plant, taking into account the evolution in technical knowledge and understanding, including feedback of operational experience, and the reference safety levels for newer plants. The results of such safety reviews are an essential input to discussions between the operating and regulatory organizations. The response of the regulator has a potentially significant impact on the operating organization's decision about the future operation of the plant.

Principle:

88. Continuation of operation of a nuclear power plant is permitted only for a suitable period of time so as to prevent 'creeping' life extension.

89. A situation where the operation of a plant would be authorized for successive limited periods could lead to difficulties because necessary decisions concerning the replacement of some plant items, or the improvement of the plant's reference safety level, could be inappropriately deferred. For older plants, the overall strategy of the operating organization for future operation is clearly stated by that organization and discussed with the regulator. After assessment of the residual potential operating lifetimes of critical items and review of the safety level of the plant, the regulator permits operation only on the basis of a sufficient residual potential operating lifetime for the plant (for example ten years) or of a precise date for the definitive shutdown of the plant.

90. Some regulators may choose to assist in the development of acceptable operating strategies by the operating organizations by defining clear requirements concerning plant items important to safety. Examples of this are providing limiting values for key parameters or specifying rules for the extension of non-destructive examination programmes when certain levels of degradation are identified.

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