

INSAG-19

Maintaining the
Design Integrity of Nuclear
Installations throughout their
Operating Life

INSAG-19

A REPORT BY THE
INTERNATIONAL NUCLEAR SAFETY ADVISORY GROUP

INSAG



IAEA

International Atomic Energy Agency

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MAINTAINING THE DESIGN INTEGRITY
OF NUCLEAR INSTALLATIONS
THROUGHOUT THEIR OPERATING LIFE

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A report by the International Nuclear Safety Advisory Group

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INTEGRITY OF NUCLEAR
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THEIR OPERATING LIFE

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A report by the
International Nuclear Safety Advisory Group

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA, 2003

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**

A nuclear power plant design is the product of the activities of many organizations, and changes to that design will occur continuously over the plant's lifetime. Reactor plants are designed to operate for a long period of time, typically 40 years, which may be extended for several decades. This period of time spans several working lifetimes of the staff of the plant, and its length represents a very specific challenge to safety and to the corporate asset management of the enterprise. It also implies that the vendor structure required to support the plant can be expected to change substantially during the plant's lifetime.

This INSAG report discusses the problem of maintaining the integrity of the design of a nuclear power plant over its entire lifetime in order to achieve a continuous high level of safety. The purpose of this report is to identify the issues and some of the principles that should be addressed, discuss some of the solutions to the problem and define the specific responsibilities of designers, operators and regulators.

This report is written for senior executives who are responsible for the safety of nuclear installations, to help them establish the necessary organization to ensure that the design integrity of the plant for which they are responsible is maintained throughout its operating life.

I am pleased to release this report to a wider audience. In particular, I hope that it will increase awareness of this important issue and help to ensure that it is adequately addressed at all nuclear installations.

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1. INTRODUCTION

1. This INSAG report discusses the problem of maintaining the integrity of design of a nuclear power plant over its entire lifetime in order to achieve a continuous high level of safety. A nuclear power plant design is the product of the activities of many organizations, and changes to that design will occur continuously over the plant's operating lifetime. Reactor plants are designed to operate for a long period of time, typically 40 years, which may be extended for several decades. This period of time spans several working lifetimes of the staff of the plant, and its length represents a very specific challenge to safety and to the corporate asset management of the enterprise. It also implies that the vendor structure required to support the plant can be expected to change substantially during the plant's lifetime.

2. The purpose of this report is to identify the issues and some of the principles that should be addressed, discuss some of the solutions to the problem, and highlight the specific responsibilities of designers, operators and regulators.

3. The issues and principles discussed here are also applicable to other nuclear installations (for example, research reactors and fuel cycle facilities).

4. This INSAG report is directed at senior executives who are responsible for:

- The overall safety of nuclear installations;
- The operation, maintenance and modification of nuclear installations;
- The original design of nuclear installations, including the nuclear steam supply, the balance of plant and major components;
- Regulatory supervision of licensee activities.

It is designed to help them establish the necessary organization to ensure that the design integrity of the plant for which they are responsible is maintained throughout the plant life.

2. THE ISSUE

5. Nuclear power plants are complex machines. They are composed of many interdependent systems which must operate in a manner that meets the design intent over a period of many decades. This long period of operation means that a plant will undergo change throughout its life. The changes can arise as a result of: the physical ageing of the plant's systems, structures and components; the obsolescence that inevitably occurs in many of its hardware and software elements; feedback from operating experience and from research on unexpected design issues arising during its life; changing engineering or regulatory standards; changes in performance expected from the plant; and changes in the organization or practices of the operating company.

6. Maintaining the very high level of safety expected of a plant requires that design changes arising from these or other sources must be made with a full understanding of all the design information for the plant and the specifications for each system and component; of the engineering compromises and assumptions made by the designers about operation and lifetime; of why the plant was designed the way it is; and of the interactions with other systems and components which could affect safety. This information will also be needed to carry out the periodic safety reviews that the regulatory body requires in many countries. The necessary knowledge of the overall plant design has to be retained in a form that is practically and easily available to the operating organization over the full operating lifetime of the plant, and until the plant is decommissioned.

7. Failure to ensure full knowledge of how plant design is maintained and to manage design changes adequately will, over the lifetime of the plant, result in decisions being taken *inter alia* on modifications, backfits, changes in operating procedures and specifications for spare parts without a full understanding of the effect that these decisions may have on the safety of the plant. Unintentional consequences that could affect the safety of the plant are likely to occur in these circumstances, and the possibility that an accident could happen as a result will likely increase.

8. When a plant is first built, its design is shared between a number of vendors: the architect-engineer; the vendor of the reactor itself and its supporting systems; the supplier of major components such as the steam generator (where appropriate); the designer of the electrical distribution systems; and many others. Most of the systems that these entities have designed are important to the safety of the plant. When the plant is put into service,

much of the detailed knowledge used in the design of such systems is transferred to the operating organization through the safety report, design manuals and other design documentation. However, the knowledge that is transferred will not be complete. Much of the highly specialized knowledge underlying the design will remain with the original designers. Over an operating lifetime of several decades for any given plant, it can be expected that some of the original design companies may be taken over by other companies or even disappear altogether.

9. The issue is made more complex as interdependences between changes that are made over a period of time can also occur, which may affect a number of systems in the plant. Interdependences can arise, for example, from power uprates, higher fuel burnup levels, longer operating cycles and life extension. Many of these changes will arise from the continuing drive that senior executives face today to maximize the economic benefits of an enterprise.

10. The need to maintain design integrity and to preserve the necessary detailed and specialized design knowledge poses a significant challenge for the organization that has overall responsibility for the safety of a plant over its operating lifetime. This organization, namely the operating organization, will therefore need to take specific and vigorous steps to assure itself that the design knowledge is maintained appropriately. The operating organization must also assure itself that a formal and rigorous design change process exists so that the actual configuration of the plant throughout its life is consistent with changes to the design, that changes can be made with full knowledge of the original design intent, the design philosophy and of all the details of implementation of the design, and that this knowledge is maintained or improved throughout the lifetime of the plant. For the process of controlling design change, the accessibility of design knowledge is not a trivial matter. The amount of data is huge, as it includes, for example, original design calculations, research results, mathematical models, commissioning test results and inspection history. Further, many design change issues can be complex.

3. THE NEED FOR A DESIGN AUTHORITY

11. An operating organization must set up internally a formal process to maintain the design integrity as soon as it takes control of the plant. This may be achieved by setting up a design capability within the operating organization,

or by having a formal external relationship with the original design organizations or their successors. There must be a formally designated entity within the operating company that takes responsibility for this process. This entity needs to formally approve all design changes. To do this, it must have sufficient knowledge of the design and of the overall basis for safety. In addition, it must have access through a formal process to all the underlying design knowledge to ensure that the original intent of the design is maintained.

12. For the purpose of this report, the entity that has this overall responsibility for the design process approves design changes and is responsible for ensuring that the requisite knowledge is maintained is referred to as the ‘design authority’. This responsibility is not in contradiction with the fact that some changes must receive approval by the regulatory body or are the result of requests from the regulatory body.

13. In the nuclear industry, the responsibilities of the original designers and the evolution of these responsibilities over time have been less clear than in some other industries¹ as a result of: (a) the current regulatory practice of holding the operating company responsible for the design as well as for its safe operation; (b) the legal position taken in most countries to hold the licensee solely liable for damages in the event of an accident; (c) the situation in the electricity generating sector of the nuclear industry, whereby each plant is frequently a unique combination of nuclear island, balance of plant and site characteristics; and (d) the consortium of architect–engineers, nuclear designers and balance of plant designers often brought together for a specific plant only.

14. This means that the operating company is frequently the only organization that has an overview of the design as a whole and of the impact of operation on the design. It is normally expected to take on the role of design authority. However, it might not — and in general does not — have all the detailed, specialized knowledge required of all the systems and components important to safety. It may therefore assign its responsibilities for some parts of the plant to other entities that do have that knowledge. Such entities are not simple subcontractors; they have a formal responsibility for maintaining their specialized knowledge of design and their competence in the detailed design process. For the purpose of this report, these other entities are referred to as

¹ For instance, in aviation, for aircraft to obtain their “Certificate of airworthiness”, a manufacturer must obtain a “Type certificate” for the model, and hold a “Design approval” and a “Manufacture approval” issued by the regulatory authority (European Regulation JAR21 or US CFR14 Part 21).

‘responsible designers’. A responsible designer may be assigned to the reactor system and its supporting systems. This would likely be the original vendor of the system. Other responsible designers may be defined for other elements such as steam generators. Figure 1 illustrates these relationships. These formal assignments may well vary from plant to plant and over the lifetime of the plant. It is essential, however, that they exist in a formal manner. The variability of these assignments leads to a requirement that the role and accountabilities of the design authority within the operating organization, the specific roles that have been assigned to the responsible designers, the precise areas that the responsible designers are held accountable for, and the processes that must be followed for each of the parties to exercise their responsibilities properly, must be defined very clearly. This requires that a systematic process exist as soon as the plant is put into service that takes account of the complexity and size of the information, together with the fact that the process may change with time.

15. It should be noted that, although a design authority may assign some specific responsibilities to responsible designers, it cannot delegate its overall responsibility for the integrity of the design of all of the plant. It must retain, therefore, sufficient knowledge of all aspects of the design to enable it to

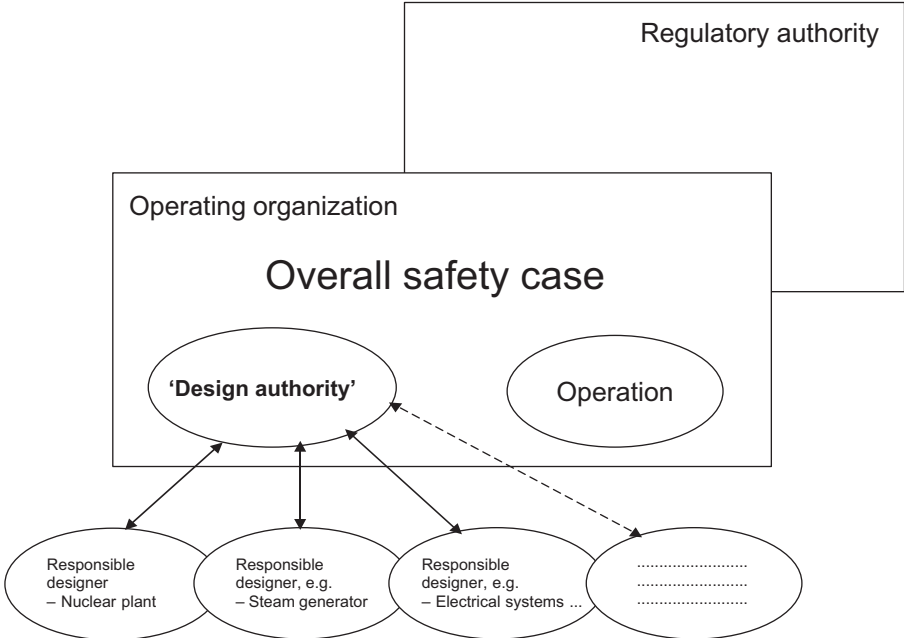


FIG. 1. Relationships between the design authority and other entities.

understand the results of the responsible designers' work, and to understand the implications of that work for the rest of the design.

4. DESIGN KNOWLEDGE NEEDED FOR CONTROL PURPOSES

16. The knowledge of the design that must be available for the process of controlling design change includes, but is not necessarily limited to:

- A detailed understanding of why the design is as it is.
- The experimental and research knowledge on which the design is based.
- The design inputs such as basic functional requirements, performance requirements, safety goals and safety principles, applicable codes, standards and regulatory requirements, design conditions, loads such as seismic loads, interface requirements, etc.
- The design outputs such as specifications, design limits, operating limits, safety limits, failure or fitness for service criteria.
- A detailed knowledge of the design calculations which demonstrate the adequacy of the design and the ability to reproduce the design calculations if needed.
- An understanding of the inspections, analysis, testing, computer code validation and acceptance criteria used by participating design organizations to verify that the design output meets the design requirements.
- The assumptions made in all the steps above, including assumptions related to operating modes or procedures, expected life history such as changes in fluence, expected transients, etc.
- The implications of operating experience on the design.

17. When a responsible designer has been assigned by the design authority for specific systems or components, this designer is expected to have the knowledge base for those assigned systems or components that is consistent with the above list.

5. RESPONSIBILITIES OF THE DESIGN AUTHORITY

18. The design authority is responsible for ensuring that the knowledge base is established, has been preserved and is expanded with experience. It is also responsible, where necessary, for recovering the knowledge base if it has been lost. It is responsible for ensuring that the knowledge of the design which is needed for the safe operation and maintenance of a plant is available to all parts of the operating organization.

19. Requirements for the management of the design of nuclear power plants are described in two IAEA publications [1, 2].

20. The Code on quality assurance (QA) [2] states that the organization having overall responsibility for the nuclear power plant shall establish a QA programme which describes the overall arrangements for management, performance and assessment of the plant design.

21. Hence, INSAG recommends that the functions of the design authority, and any responsible designers be defined in the overall QA programme. The functions in paras 22–25 can be derived from the description of the previously mentioned issues.

22. The design authority, or a responsible designer in its assigned area, must review, verify and approve (or reject) design changes to the plant. The capability and authority to reject proposed design changes that do not maintain the design integrity is a vitally important role of the design authority, or of a responsible designer in its assigned area. This role must be clearly defined and recognized by the operating company in its formal documentation. Any distribution of that authority, for example between the corporate office and the plant site of the operating organization to reflect different levels of approval, must be identified clearly and included in the documentation. Design changes include field changes, modifications and the acceptance of non-conforming items for repair or use without modification.

23. The design authority is responsible for design configuration control by maintaining (or by ensuring that responsible designers maintain) up to date records of all the drawings, specifications, manuals, design standards, engineering calculations, supporting data and theoretical bases for the plant systems, structures and components.

24. The design authority must control necessary interfaces with responsible designers or other suppliers engaged in design work.

25. It must ensure that the necessary engineering and scientific skills and knowledge are maintained, including any research programmes that are needed to keep that knowledge current.

6. FORMAL ARRANGEMENTS

26. The operating company has overall responsibility for the safe operation and maintenance of the design integrity of a plant. The establishment of the design authority should be the operating company's means of ensuring that the design integrity is maintained.

27. The original designers of a plant meet the attributes of a design authority during the original design, construction and commissioning of the plant. Their knowledge and skills represent their commercial advantage in the marketplace. Formal commercial arrangements are therefore to be made by all operating companies to either:

- Develop the complete design authority role within their own organizations and hence obtain and maintain all the information held by the original designers; or
- Assign the original designers or their replacements the formal responsibility of 'responsible designer'; or
- Define some combination of these two arrangements.

28. As stated above, the precise tasks and functions of the design authority and any responsible designer must be established very clearly in formal documentation. Under this scheme, however, the operating company retains overall responsibility for the implementation and effectiveness of the programme. It must maintain this programme over time, and in particular it must have a strategy to anticipate the possible disappearance of some of the responsible designers. The operating company must also ensure that the safety impact of changes, both of individual changes and a series of multiple changes that may have significant interdependences, are properly analysed and understood.

7. REGULATORY OVERSIGHT

29. Given that the inadequate management of design integrity can lead to a significant increase in risk, INSAG recommends that regulatory bodies verify that appropriate programmes are established and that the design authority and any responsible designers are identified, together with the boundaries of their functions. Regulatory bodies also need to ascertain that design integrity maintenance programmes are effective, that adequate arrangements exist to ensure that design knowledge is used appropriately in the process for controlling design change over the operating lifetime of plants and that the safety impacts of multiple changes have been properly analysed and understood.

30. In the future, commercial pressures may well require that the nuclear industry produce many identical copies of a given design which is licensable without change in different countries. This implies that an internationally agreed process exists for the regulatory approval or licensing of a design that could be valid for different countries. Such an arrangement is likely to be similar to that used in the aircraft industry and would bring the concept of design authority more in line with many other engineering industries, in that the original designer is likely to maintain the responsibility of design authority throughout the operating life of the plant. In such a situation, the role of the design authority becomes even more crucial. In particular, it has to be clearly identified by whom and by which mechanisms design changes throughout the operating lifetime of the plant are decided, whether or not the changes are generic and affect all copies of the plant or are specific to a given plant, and how operating experience from all copies of the plant design are made available to other operators and licensees to ensure the safety of all plants concerned.

8. CONCLUSIONS

31. The responsibilities and attributes of a design authority within an operating organization, and the type and nature of the formal responsibilities held by responsible designers, must be developed and maintained over the operating lifetime of the nuclear power plant.

32. Although current national and international codes of practice for the safety of plants describe standard arrangements for the management of design, design change control, configuration control, etc., they do not cover the overall issue that the design integrity of nuclear installations must be maintained throughout their operating lifetime.

33. The need for an authority that maintains the design integrity over the operating lifetime of a plant needs to be fully recognized by operating organizations as an essential part of their primary responsibility for safety.

34. It is important that senior executives of operating organizations ask themselves and their staff to what extent they have the appropriate organizational, process and contractual means to ensure and master the objectives described in this report, and, if these means are lacking, to take appropriate corrective action.

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