

IAEA Safety Standards

for protecting people and the environment

Human Factors Engineering in the Design of Nuclear Power Plants

Specific Safety Guide

No. SSG-51



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International Atomic Energy Agency



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The publications by means of which the IAEA establishes standards are issued in the **IAEA Safety Standards Series**. This series covers nuclear safety, radiation safety, transport safety and waste safety. The publication categories in the series are **Safety Fundamentals**, **Safety Requirements** and **Safety Guides**.

Information on the IAEA's safety standards programme is available on the IAEA Internet site

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The site provides the texts in English of published and draft safety standards. The texts of safety standards issued in Arabic, Chinese, French, Russian and Spanish, the IAEA Safety Glossary and a status report for safety standards under development are also available. For further information, please contact the IAEA at: Vienna International Centre, PO Box 100, 1400 Vienna, Austria.

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HUMAN FACTORS ENGINEERING IN THE DESIGN OF NUCLEAR POWER PLANTS



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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".

IAEA SAFETY STANDARDS SERIES No. SSG-51

HUMAN FACTORS ENGINEERING IN THE DESIGN OF NUCLEAR POWER PLANTS

SPECIFIC SAFETY GUIDE

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA, 2019

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FOREWORD

by Yukiya Amano
Director General

The IAEA's Statute authorizes the Agency to “establish or adopt... standards of safety for protection of health and minimization of danger to life and property” — standards that the IAEA must use in its own operations, and which States can apply by means of their regulatory provisions for nuclear and radiation safety. The IAEA does this in consultation with the competent organs of the United Nations and with the specialized agencies concerned. A comprehensive set of high quality standards under regular review is a key element of a stable and sustainable global safety regime, as is the IAEA's assistance in their application.

The IAEA commenced its safety standards programme in 1958. The emphasis placed on quality, fitness for purpose and continuous improvement has led to the widespread use of the IAEA standards throughout the world. The Safety Standards Series now includes unified Fundamental Safety Principles, which represent an international consensus on what must constitute a high level of protection and safety. With the strong support of the Commission on Safety Standards, the IAEA is working to promote the global acceptance and use of its standards.

Standards are only effective if they are properly applied in practice. The IAEA's safety services encompass design, siting and engineering safety, operational safety, radiation safety, safe transport of radioactive material and safe management of radioactive waste, as well as governmental organization, regulatory matters and safety culture in organizations. These safety services assist Member States in the application of the standards and enable valuable experience and insights to be shared.

Regulating safety is a national responsibility, and many States have decided to adopt the IAEA's standards for use in their national regulations. For parties to the various international safety conventions, IAEA standards provide a consistent, reliable means of ensuring the effective fulfilment of obligations under the conventions. The standards are also applied by regulatory bodies and operators around the world to enhance safety in nuclear power generation and in nuclear applications in medicine, industry, agriculture and research.

Safety is not an end in itself but a prerequisite for the purpose of the protection of people in all States and of the environment — now and in the future. The risks associated with ionizing radiation must be assessed and controlled without unduly limiting the contribution of nuclear energy to equitable and sustainable development. Governments, regulatory bodies and operators everywhere must ensure that nuclear material and radiation sources are used beneficially, safely and ethically. The IAEA safety standards are designed to facilitate this, and I encourage all Member States to make use of them.

THE IAEA SAFETY STANDARDS

BACKGROUND

Radioactivity is a natural phenomenon and natural sources of radiation are features of the environment. Radiation and radioactive substances have many beneficial applications, ranging from power generation to uses in medicine, industry and agriculture. The radiation risks to workers and the public and to the environment that may arise from these applications have to be assessed and, if necessary, controlled.

Activities such as the medical uses of radiation, the operation of nuclear installations, the production, transport and use of radioactive material, and the management of radioactive waste must therefore be subject to standards of safety.

Regulating safety is a national responsibility. However, radiation risks may transcend national borders, and international cooperation serves to promote and enhance safety globally by exchanging experience and by improving capabilities to control hazards, to prevent accidents, to respond to emergencies and to mitigate any harmful consequences.

States have an obligation of diligence and duty of care, and are expected to fulfil their national and international undertakings and obligations.

International safety standards provide support for States in meeting their obligations under general principles of international law, such as those relating to environmental protection. International safety standards also promote and assure confidence in safety and facilitate international commerce and trade.

A global nuclear safety regime is in place and is being continuously improved. IAEA safety standards, which support the implementation of binding international instruments and national safety infrastructures, are a cornerstone of this global regime. The IAEA safety standards constitute a useful tool for contracting parties to assess their performance under these international conventions.

THE IAEA SAFETY STANDARDS

The status of the IAEA safety standards derives from the IAEA's Statute, which authorizes the IAEA to establish or adopt, in consultation and, where appropriate, in collaboration with the competent organs of the United Nations and with the specialized agencies concerned, standards of safety for protection of health and minimization of danger to life and property, and to provide for their application.

With a view to ensuring the protection of people and the environment from harmful effects of ionizing radiation, the IAEA safety standards establish fundamental safety principles, requirements and measures to control the radiation exposure of people and the release of radioactive material to the environment, to restrict the likelihood of events that might lead to a loss of control over a nuclear reactor core, nuclear chain reaction, radioactive source or any other source of radiation, and to mitigate the consequences of such events if they were to occur. The standards apply to facilities and activities that give rise to radiation risks, including nuclear installations, the use of radiation and radioactive sources, the transport of radioactive material and the management of radioactive waste.

Safety measures and security measures¹ have in common the aim of protecting human life and health and the environment. Safety measures and security measures must be designed and implemented in an integrated manner so that security measures do not compromise safety and safety measures do not compromise security.

The IAEA safety standards reflect an international consensus on what constitutes a high level of safety for protecting people and the environment from harmful effects of ionizing radiation. They are issued in the IAEA Safety Standards Series, which has three categories (see Fig. 1).

Safety Fundamentals

Safety Fundamentals present the fundamental safety objective and principles of protection and safety, and provide the basis for the safety requirements.

Safety Requirements

An integrated and consistent set of Safety Requirements establishes the requirements that must be met to ensure the protection of people and the environment, both now and in the future. The requirements are governed by the objective and principles of the Safety Fundamentals. If the requirements are not met, measures must be taken to reach or restore the required level of safety. The format and style of the requirements facilitate their use for the establishment, in a harmonized manner, of a national regulatory framework. Requirements, including numbered ‘overarching’ requirements, are expressed as ‘shall’ statements. Many requirements are not addressed to a specific party, the implication being that the appropriate parties are responsible for fulfilling them.

¹ See also publications issued in the IAEA Nuclear Security Series.

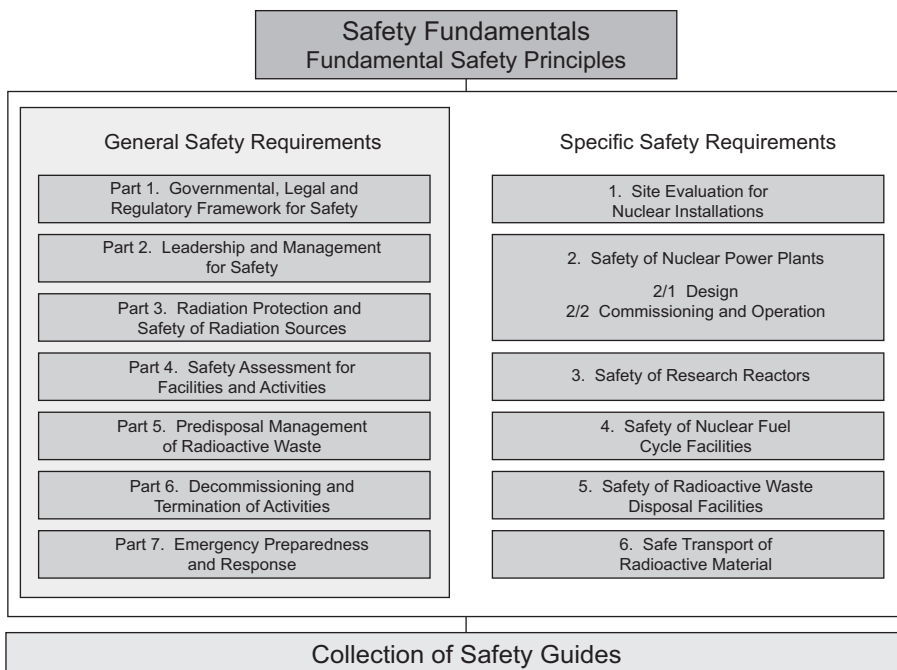


FIG. 1. The long term structure of the IAEA Safety Standards Series.

Safety Guides

Safety Guides provide recommendations and guidance on how to comply with the safety requirements, indicating an international consensus that it is necessary to take the measures recommended (or equivalent alternative measures). The Safety Guides present international good practices, and increasingly they reflect best practices, to help users striving to achieve high levels of safety. The recommendations provided in Safety Guides are expressed as ‘should’ statements.

APPLICATION OF THE IAEA SAFETY STANDARDS

The principal users of safety standards in IAEA Member States are regulatory bodies and other relevant national authorities. The IAEA safety standards are also used by co-sponsoring organizations and by many organizations that design, construct and operate nuclear facilities, as well as organizations involved in the use of radiation and radioactive sources.

The IAEA safety standards are applicable, as relevant, throughout the entire lifetime of all facilities and activities — existing and new — utilized for peaceful purposes and to protective actions to reduce existing radiation risks. They can be used by States as a reference for their national regulations in respect of facilities and activities.

The IAEA's Statute makes the safety standards binding on the IAEA in relation to its own operations and also on States in relation to IAEA assisted operations.

The IAEA safety standards also form the basis for the IAEA's safety review services, and they are used by the IAEA in support of competence building, including the development of educational curricula and training courses.

International conventions contain requirements similar to those in the IAEA safety standards and make them binding on contracting parties. The IAEA safety standards, supplemented by international conventions, industry standards and detailed national requirements, establish a consistent basis for protecting people and the environment. There will also be some special aspects of safety that need to be assessed at the national level. For example, many of the IAEA safety standards, in particular those addressing aspects of safety in planning or design, are intended to apply primarily to new facilities and activities. The requirements established in the IAEA safety standards might not be fully met at some existing facilities that were built to earlier standards. The way in which IAEA safety standards are to be applied to such facilities is a decision for individual States.

The scientific considerations underlying the IAEA safety standards provide an objective basis for decisions concerning safety; however, decision makers must also make informed judgements and must determine how best to balance the benefits of an action or an activity against the associated radiation risks and any other detrimental impacts to which it gives rise.

DEVELOPMENT PROCESS FOR THE IAEA SAFETY STANDARDS

The preparation and review of the safety standards involves the IAEA Secretariat and five safety standards committees, for emergency preparedness and response (EPReSC) (as of 2016), nuclear safety (NUSSC), radiation safety (RASSC), the safety of radioactive waste (WASSC) and the safe transport of radioactive material (TRANSSC), and a Commission on Safety Standards (CSS) which oversees the IAEA safety standards programme (see Fig. 2).

All IAEA Member States may nominate experts for the safety standards committees and may provide comments on draft standards. The membership of

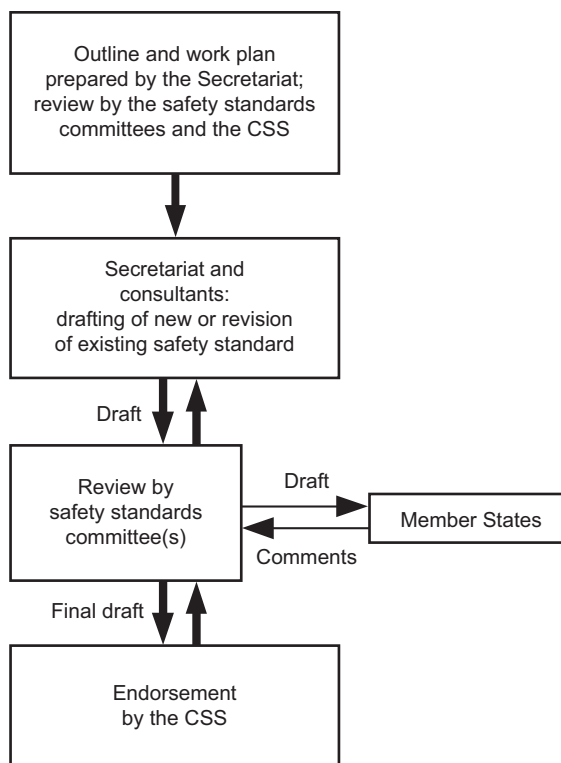


FIG. 2. The process for developing a new safety standard or revising an existing standard.

the Commission on Safety Standards is appointed by the Director General and includes senior governmental officials having responsibility for establishing national standards.

A management system has been established for the processes of planning, developing, reviewing, revising and establishing the IAEA safety standards. It articulates the mandate of the IAEA, the vision for the future application of the safety standards, policies and strategies, and corresponding functions and responsibilities.

INTERACTION WITH OTHER INTERNATIONAL ORGANIZATIONS

The findings of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) and the recommendations of international

expert bodies, notably the International Commission on Radiological Protection (ICRP), are taken into account in developing the IAEA safety standards. Some safety standards are developed in cooperation with other bodies in the United Nations system or other specialized agencies, including the Food and Agriculture Organization of the United Nations, the United Nations Environment Programme, the International Labour Organization, the OECD Nuclear Energy Agency, the Pan American Health Organization and the World Health Organization.

INTERPRETATION OF THE TEXT

Safety related terms are to be understood as defined in the IAEA Safety Glossary (see <http://www-ns.iaea.org/standards/safety-glossary.htm>). Otherwise, words are used with the spellings and meanings assigned to them in the latest edition of The Concise Oxford Dictionary. For Safety Guides, the English version of the text is the authoritative version.

The background and context of each standard in the IAEA Safety Standards Series and its objective, scope and structure are explained in Section 1, Introduction, of each publication.

Material for which there is no appropriate place in the body text (e.g. material that is subsidiary to or separate from the body text, is included in support of statements in the body text, or describes methods of calculation, procedures or limits and conditions) may be presented in appendices or annexes.

An appendix, if included, is considered to form an integral part of the safety standard. Material in an appendix has the same status as the body text, and the IAEA assumes authorship of it. Annexes and footnotes to the main text, if included, are used to provide practical examples or additional information or explanation. Annexes and footnotes are not integral parts of the main text. Annex material published by the IAEA is not necessarily issued under its authorship; material under other authorship may be presented in annexes to the safety standards. Extraneous material presented in annexes is excerpted and adapted as necessary to be generally useful.

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1. INTRODUCTION

BACKGROUND

1.1. This Safety Guide provides recommendations on the application of human factors engineering (HFE)¹ to meet the requirements established in IAEA Safety Standards Series Nos SSR-2/1 (Rev. 1), Safety of Nuclear Power Plants: Design [1], SSR-2/2 (Rev. 1), Safety of Nuclear Power Plants: Commissioning and Operation [2], and GSR Part 4 (Rev. 1), Safety Assessment for Facilities and Activities [3].

1.2. This Safety Guide takes into account developments, experience and practices in integrating HFE into the design of nuclear power plants throughout their lifetime. It references and takes into account other IAEA Safety Standards Series publications that are relevant and related to the integration of HFE into design. These include IAEA Safety Standards Series No. GSR Part 2, Leadership and Management for Safety [4], and its supporting Safety Guides: IAEA Safety Standards Series Nos GS-G-3.1, Application of the Management System for Facilities and Activities [5], and GS-G-3.5, The Management System for Nuclear Installations [6].

1.3. The main topical areas for which this Safety Guide provides guidance are:

- The HFE processes to be applied in the design of human–machine interface (HMI) for all plant states, for achieving compliance with the requirements established in SSR-2/1 (Rev. 1) [1];
- Integration of HFE into the design of a nuclear power plant throughout its lifetime for achieving compliance with the requirements established in GSR Part 2 [4];
- Human performance monitoring and evaluation throughout the lifetime of the nuclear power plant;
- Integration of HFE into safety processes, applications and product selection.

¹ ‘Human factors engineering’ is engineering in which factors that could influence human performance and that could affect safety are understood and are taken into account, especially in the design and operation of facilities.

1.4. This Safety Guide considers HFE aspects for several important processes linked to design, such as:

- Development and review of the safety analysis report;
- Plant modifications for achieving compliance with the requirements established in SSR-2/2 (Rev. 1) [2];
- Periodic safety review.

1.5. This Safety Guide considers relevant HFE aspects for the design and use of computerized procedures.

1.6. This Safety Guide considers relevant HFE aspects for the selection, procurement, integration and use of several products in existing plant systems, such as:

- Personal protective equipment (e.g. personal protective equipment used during maintenance activities, inspections, accident monitoring and operation of equipment for the mitigation of severe accidents);
- Commercial off the shelf products;
- Mobile devices (e.g. hand-held, portable and wearable devices).

1.7. Additional guidance on HFE in the design and development of HMIs is available from organizations that develop industrial standards (see the Annex). Such standards provide much greater detail than is appropriate for IAEA safety standards. It is expected that this Safety Guide will be used in conjunction with such detailed industry standards.

OBJECTIVE

1.8. The objective of this Safety Guide is to provide a structured approach for, and guidance on, the application of HFE in the design and modification of HMIs in order to minimize the risk of human errors and optimize human performance to ensure safe operation of nuclear power plants.

1.9. The Safety Guide identifies the input information necessary to design and validate HMIs, which is the basis for human physical and cognitive processes.

SCOPE

1.10. This Safety Guide applies primarily to land based, stationary, commercial nuclear power plants. It could also be applied, using appropriate judgement, to other reactor types (e.g. small modular reactors), to determine the guidance that has to be considered in design.

1.11. The recommendations of this Safety Guide are to be applied in accordance with a graded approach, as set out in GSR Part 2 [4].

1.12. This Safety Guide applies to the application of HFE in the design, operation and maintenance of HMIs for new plants, as well as for modifications of HMIs of existing plants.

1.13. This Safety Guide is intended for use by organizations involved in the design, manufacture, construction, modification, maintenance, operation and decommissioning of nuclear power plants, in analysis, verification, validation, implementation and monitoring, and in the provision of technical support, as well as by regulatory bodies.

1.14. This Safety Guide does not address the application of HFE for purposes of nuclear security.

STRUCTURE

1.15. Section 2 provides guidance for the management of an HFE programme. Section 3 provides recommendations for review of operating experience; function analysis; function allocation; task analysis; analysis of staffing, organization and qualification; and treatment of important human tasks. Section 4 provides recommendations for the application of HFE in design. Section 5 provides guidance on the verification and validation of human factors in the design process. Section 6 provides recommendations on the implementation of the design of HMIs. Section 7 provides recommendations on human performance monitoring aspects of systems performance during plant operation. Section 8 provides recommendations on the application of HFE in design for computerized procedures. Section 9 provides recommendations on the integration of HFE into safety processes. Section 10 provides recommendations on the application of HFE in the specification and selection of products for subcontracted procurements. The Annex provides a list of international industrial standards for instrumentation

and control (I&C) and HFE that have a strong relationship with the major topical areas of this Safety Guide.

2. HUMAN FACTORS ENGINEERING PROGRAMME MANAGEMENT

GENERAL

2.1. GSR Part 2 [4] establishes requirements for the management system for all types of facility and activity.

2.2. Requirement 6 of GSR Part 2 [4] states: **“The management system shall integrate its elements, including safety, health, environmental, security, quality, human-and-organizational-factor, societal and economic elements, so that safety is not compromised.”**

2.3. Paragraph 4.24 of GSR Part 2 [4] states:

“Competences to be sustained in-house by the organization shall include: competences for leadership at all management levels; competences for fostering and sustaining a strong safety culture; and expertise to understand technical, human and organizational aspects relating to the facility or the activity in order to ensure safety.”

2.4. HFE should be applied to ensure the successful integration of human characteristics and capabilities with the design, commissioning, operation and maintenance of the nuclear power plant.

2.5. The integration of HFE into the design should be planned and documented, and should be an integral part of any nuclear power plant project.

2.6. An HFE programme should be developed and documented.

2.7. In the HFE programme, the nuclear power plant should be treated as a system comprising humans, technology and the organization, and the dynamic interactions within and among all relevant factors should be considered:

- Human factors (e.g. knowledge and expertise, cognition, performance expectations, motivation, stress, strength and body size);
- Technical factors (e.g. technology, including controls and displays, software, hardware, tools, equipment, plant design and plant processes);
- Organizational factors (e.g. management system, organizational structure, governance, resources, staffing levels, and the roles and responsibilities of managers and other plant personnel).

2.8. Humans, technology and the organization, as well as their interaction, should be considered in an integrated manner throughout the planning and execution of the HFE programme, during the design of the HMI and for resource allocation for all plant states.

2.9. In the HFE programme, a questioning and learning attitude should be applied to accepted design methods and solutions, with newly developed information, analysis methods, knowledge and features of new technology taken into account.

2.10. The HFE programme should be applied using the graded approach, as set out in GSR Part 2 [4], in order to identify the appropriate level of rigour, resources and detail to be applied.

2.11. The HFE programme should outline the HFE activities as well as the inputs to, and outputs from, these processes. HFE activities include analyses, design of the HMI, evaluations such as verification and validation, and monitoring of human performance (see para. 2.19).

2.12. The HFE programme should specify how HFE is integrated with other plant design or modification activities.

2.13. The HFE programme should identify the necessary coordination between personnel responsible for the HFE programme, project and design authorities, and personnel from other organizational units in the plant.

2.14. A process for communicating the outputs from analyses to the responsible engineering organizational units and for ensuring that the outputs have been addressed should be established and documented.

2.15. The HFE programme should identify the relevant organizational requirements and competence requirements (e.g. qualifications, skills, knowledge and training) for personnel performing HFE activities.

2.16. The HFE programme should provide a framework for documenting and tracking HFE related issues that are identified by the HFE processes.

2.17. The HFE programme should specify that the design team have a member or members with HFE expertise.

2.18. For the design of a new plant, the operating organization should assure itself that the intended plant design meets appropriate HFE standards and the recommendations of this Safety Guide.

THE HUMAN FACTORS ENGINEERING PROCESS MODEL

2.19. The overall HFE process can be divided into the following HFE activities:

- Programme management;
- Analysis;
- Design;
- Verification and validation;
- Implementation of the design;
- Human performance monitoring.

HUMAN FACTORS ENGINEERING ACTIVITIES WITHIN AN ENGINEERING PROJECT

2.20. HFE activities should be integrated into the basic stages of an engineering project as illustrated in Fig. 1.

2.21. The following should be considered as HFE inputs for the concept development stage:

- HFE programme management should identify a systematic, integrated HFE process, should outline responsibilities for HFE and should present expected design inputs and outputs for the HFE process.
- HFE programme management should establish a capable organizational unit with responsibility for human factors and with sufficient authority, at all hierarchical levels, to effect the necessary design changes to meet HFE expectations.

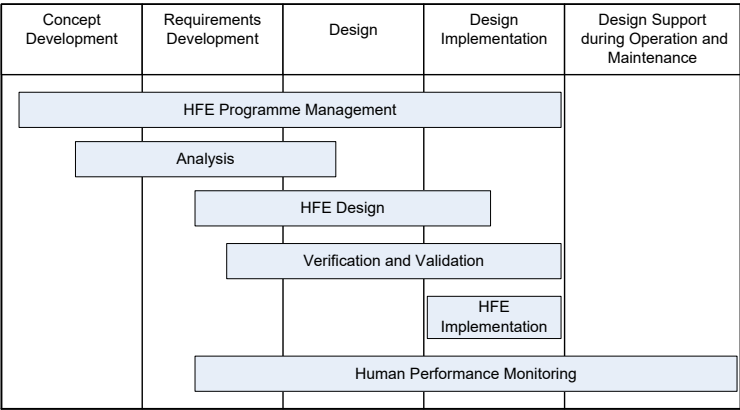


FIG. 1. An example of a generic engineering project, indicating when human factors engineering (HFE) activities are undertaken.

- HFE programme management should identify the most recent HFE relevant codes, standards, methodologies and guidelines applicable to the engineering project.
- HFE analyses should identify relevant operating experience (both positive and negative), with a focus on human performance issues and potential human errors and their mitigation.
- HFE analyses should provide inputs (such as operator needs and requirements) useful for defining and selecting relevant design choices.
- HFE analyses should be used to identify the organizational structure that frames the use of the HFE programme (i.e. the identification of users, their roles and responsibilities, required qualifications and regulatory requirements) and supports operation and maintenance.
- HFE analyses should provide a preliminary understanding of the allocation of functions and the human information requirements for monitoring and controlling, where applicable, the functions of systems in the plant.
- HFE analyses should provide insights and consideration of how operators are expected to respond in the presence of control system failures and HMI failures.

2.22. The following should be considered as HFE inputs for the requirements development stage:

- Results of the function analysis that identify the functional requirements for structures, systems and components.

- Results of task analyses that provide insight into:
 - What kind of alarms, information, procedures, controls and system feedback are necessary;
 - The possible sequence of tasks;
 - Potential human errors and considerations that impact human performance and provide error reducing and performance enhancing design features;
 - Safety significant, complex tasks that warrant detailed technical and HFE analyses;
 - Time constraints for significant tasks;
 - Specific knowledge, skills and abilities needed by personnel in order to perform their assigned task(s) and meet operational objectives;
 - Collaboration and coordination between individuals or groups that are necessary to support the task.
- Specific HFE design principles and HMI design guidelines for developing technical specifications for vendors and for incorporating them into HFE specifications for vendors.

2.23. The following should be considered as HFE inputs for the design stage:

- Updates to HFE requirements owing to design evolution or changes in standards;
- Specific HFE design principles and HMI design guidelines for the specification of plant and workspace design and layout, and HMI components and their architecture;
- Specific HFE design principles and HMI design guidelines for maintenance and testing;
- The potential impact of new or modified designs on human performance, and the development of procedures and training;
- Collection and analysis of user feedback through early HFE analyses in the form of usability testing and user reviews of prototypes and concepts;
- Insight into the scope, content and usability of operating procedures used to support the execution of safety critical tasks;
- Insight into the scope and content of training.

2.24. The following should be considered as HFE inputs for the design implementation stage:

- Verification of design implementation against previously identified HFE design principles and applicable HFE design codes, standards and guidelines;

- Verification of design implementation to ensure all information and controls required for carrying out tasks have been provided in the design;
- Validation in respect of human factors to ascertain the degree to which the HMI design and supporting mechanisms facilitate the achievement of safe operation of the plant;
- Confirmation of the feasibility of important human tasks in the probabilistic and deterministic safety analyses through validation in respect of human factors;
- Confirmation of the completion of HFE analyses and of HFE inputs into the design in accordance with the HFE programme and regulatory expectations.

2.25. Throughout the design stages, consideration should be given to the constraints of the technology being considered (e.g. availability, reliability, bandwidth, and the general acceptance and familiarity of the personnel with the technology). For example, although personnel accept the use of digital technology in everyday life, the designer may need to consider whether the use of virtual reality or augmented reality would cause difficulties for personnel.

2.26. Human performance monitoring in support of design should be conducted during the operation and maintenance stages in order to verify that analyses and assumptions from the design stage remain valid throughout the lifetime of the plant.

2.27. HFE activities supporting analyses, design, and verification and validation should be conducted in an iterative manner consistent with the overall design project.

2.28. HFE activities that support analyses, design, and verification and validation are often collaborative and should involve a multidisciplinary team with HFE expertise. In order to be properly addressed, the results of HFE analyses, design, and verification and validation activities should be communicated to other organizational units participating in the design.

2.29. The HMI and its functionality should be treated from the perspective of the HMI being part of an integrated whole and not merely an assembly of discrete controls, indicators and systems.

3. ANALYSIS

REVIEW OF OPERATING EXPERIENCE

3.1. Paragraph 5.28 of SSR-2/2 (Rev. 1) [2] states: “Events with significant implications for safety shall be investigated to identify their direct and root causes, including causes relating to equipment design, operation and maintenance, or to human and organizational factors.”

3.2. Data and conclusions from event analyses should be used as HFE inputs for the design of a new plant or the modification of an existing plant.

3.3. The review of operating experience should provide information regarding current work practices for the following purposes: (i) to assess the potential impact of planned changes; (ii) to evaluate operational problems and difficulties in current designs that might need to be addressed during plant modernization and modifications to plant components; and (iii) to evaluate relevant industry experience with design options for I&C systems and HMI technology for their potential to improve plant efficiency and safety.

3.4. In the review of operating experience, both positive and negative aspects of performance and design should be analysed.

3.5. The review of operating experience should take into account:

- Applicable HFE related issues identified in the review of operating experience at the nuclear power plant;
- Insights from experience identified by plant personnel;
- Issues identified in the review of operating experience at other nuclear power plants and in other industries.

3.6. Operating experience data for any of the following should be taken into account:

- Minor problems (e.g. near misses or low level events) that are often precursors or contributors to more significant events;
- Adverse trends that could indicate a reduction in reliability;
- Data on root causes that could point to a need for improvements in design;
- Evidence of influences and trends in the organizational culture that could prove problematic for future operations;

- Corrective actions and their implementation;
- Recurring events;
- Reviews of maintenance practices;
- Industry communications on best practices.

3.7. IAEA Safety Standards Series No. SSG-50, Operating Experience Feedback for Nuclear Installations [7] provides recommendations for establishing, implementing, assessing and continuously improving an operating experience programme for nuclear installations to prevent or minimize the risk of future events by learning from events that have already occurred at the installation or elsewhere.

FUNCTION ANALYSIS

3.8. A function analysis should be conducted for all plant states to ensure that the functions necessary to accomplish safe operation of the nuclear power plant are sufficiently well defined and properly analysed.

3.9. The function analysis should provide a framework for understanding the role of personnel in controlling plant processes.

3.10. The function analysis should be used to identify the information (e.g. information on when a function is needed, available, operating, achieving its purpose or terminating) and controls that are necessary for the personnel to accomplish operational objectives.

3.11. The function analysis should provide time and performance requirements and constraints for performing the functions.

3.12. Human, technical and organizational factors should be considered when performing the function analysis.

3.13. The function analysis should be used to identify high level acceptance criteria associated with maintaining safe operation of the plant.

3.14. As part of the function analysis, the following should be analysed and documented:

- High level functions that ensure safe operation of the plant;

- Relationships (e.g. the plant configurations or success paths²) between high level functions and the plant systems responsible for performing those functions;
- The decomposition of high level functions into lower level functions that can be mapped to tasks to be performed by plant automation or by humans, or by humans and automation jointly;
- A framework for determining the roles and responsibilities of personnel and automation.

3.15. The combination of systems and processes used to achieve a high level function and the human actions required for the success path should be documented as part of the function analysis.

3.16. Dependencies that might exist among plant functions, plant systems and their support systems should be documented as part of the function analysis.

FUNCTION ALLOCATION

3.17. Allocation of functions should be conducted for all plant states to ensure that the functions necessary to accomplish safe operation of the nuclear power plant are sufficiently well defined and properly analysed.

3.18. The allocation of functions to personnel and automation should take into account human capabilities (e.g. the ability to improvise, flexibility, judgement and pattern detection) and machine strengths (e.g. rapidity and simultaneous processing of complex operations).

3.19. Human, technical and organizational factors should be considered when performing function allocation.

3.20. The design team should use knowledge of physical processes, current industry technology, operating experience, and human performance strengths and weaknesses to allocate functions to personnel and automation (e.g. hardware and software).

² A ‘success path’ is a set of selected structures, systems and components that provide high confidence that a nuclear power plant will successfully reach a safe state after an accident occurs.

3.21. Function allocation makes use of the function analysis of plant control systems and establishes the allocation of control processes, which might be assigned in the following ways:

- To personnel (e.g. manual control, with no automation).
- To automatic systems (e.g. fully automatic control and passive, self-controlling phenomena).
- To a combination of personnel and automation, for example:
 - Shared operation (i.e. the automatic operation of some aspects of a function, with other aspects performed manually);
 - Operation by consent or delegation (i.e. automation takes control of a function when personnel have given permission and the situation permits);
 - Operation by exception (i.e. automatic operation of a function, unless there are specific predefined situations or circumstances necessitating manual control).

3.22. In addition to consideration of human capabilities, when allocating functions, the designer should also take into account such factors as whether the technology is acceptable to personnel, timing capabilities associated with systems response, and considerations for defence in depth.

3.23. If the achievement of a control function requires the allocation of overlapping and redundant responsibilities to personnel and to automation (e.g. assigning personnel the responsibility of monitoring and maintaining supervisory control over automatic systems), this allocation should be documented.

3.24. The nature and scope of human tasks should be documented for all functions.

3.25. The allocation of functions should be analysed for various operational states and accident conditions.

3.26. Function analysis and the allocation of functions should take account of requirements associated with the implementation of severe accident management guidelines.

3.27. The allocation of functions should be traceable from the function to the associated system or component.

TASK ANALYSIS

3.28. The approach to task analysis should take into account the plant states and the groups of operating personnel (e.g. reactor operator, turbine operator, shift supervisor, field operator, safety engineer, and operation and maintenance staff) that are relevant to the task being analysed.

3.29. Human, technical and organizational factors (e.g. leadership, management and communication) should be considered when conducting task analysis.

3.30. Task analysis should be conducted to analyse and document the physical and cognitive activities associated with performing tasks assigned to personnel.

3.31. Task analysis should include the context of the task from the standpoint of the user who will accomplish the task.

3.32. The role and activities of individuals in a nuclear power plant are wide ranging, and, therefore, the scope of analysis should be justified and will often include:

- Tasks that are performed in different locations (e.g. control room, supplementary control room, local control stations, emergency response facilities);
- Tasks that differ depending on the plant state;
- Tasks that require individual work and/or cooperation or exchanges between different organizational units (e.g. operations, maintenance, procedures development and computer systems engineering) and interested parties;
- Tasks that sometimes have to be performed under time pressure or harsh environmental conditions and contexts, or that are safety critical and rarely performed.

3.33. Risk and safety aspects should also be considered when identifying the tasks to be included in the task analysis, which could include:

- Tasks posing an occupational risk to personnel;
- Tasks credited in the safety analysis;
- Tasks identified from operating experience as challenging or prone to error;
- Tasks identified as difficult by operating personnel and for which no plans have been made to automate that task;
- Tasks that are critical for maintaining the plant in a safe state or restoring it to a safe state following an event.