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The Role of Human and Organisational Factors in Nuclear Power Plant Modifications

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NUCLEAR ENERGY AGENCY
ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

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The mission of the NEA is:

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- to provide authoritative assessments and to forge common understandings on key issues as input to government decisions on nuclear energy policy and to broader OECD policy analyses in areas such as energy and sustainable development.

Specific areas of competence of the NEA include safety and regulation of nuclear activities, radioactive waste management, radiological protection, nuclear science, economic and technical analyses of the nuclear fuel cycle, nuclear law and liability, and public information. The NEA Data Bank provides nuclear data and computer program services for participating countries.

In these and related tasks, the NEA works in close collaboration with the International Atomic Energy Agency in Vienna, with which it has a Co-operation Agreement, as well as with other international organisations in the nuclear field.

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FOREWORD

The NEA Working Group on Human and Organisational Factors (WGHOF) is tasked to improve the current understanding of human and organisational performance and the way in which this impacts upon nuclear safety. In order to further the understanding of human and organisational performance during the nuclear plant modification process, the WGHOF organised a workshop in 2003 entitled the "Role of Human and Organisational Factors in Nuclear Plant Modifications". This technical opinion paper represents the consensus of the NEA member countries which attended.

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EXECUTIVE SUMMARY

This technical opinion paper (TOP) represents the consensus of specialists in human and organisational factors (HOF) in the NEA Committee on Safety of Nuclear Installations (CSNI) member countries on commendable practices and approaches to incorporating a suitable treatment of HOF in the nuclear plant modification process. The TOP stems from the outcomes of a workshop, organised in 2003 by the NEA Committee on Safety of Nuclear Installations (CSNI) on Modifications at Nuclear Plants – Operating Experience, Safety Significance and Role of Human Factors and a CSNI report NEA/CSNI/R(2005)10 [1].

Nuclear plant modifications may be initiated for different reasons. Examples are physical ageing of plant systems, structures and components; obsolescence in hardware and software; feedback from operating experience; opportunities for improved safety or plant capability, regulatory requirements; etc. All modifications that have a potential influence on nuclear safety should be controlled through a formalised plant modification process.

Nuclear licensees should put in place arrangements to ensure that a suitable consideration of HOF is systematically integrated within the plant modification process. The process should be designed to support timely and effective dialogue between HOF specialists and other technical disciplines involved in the modification process. Therefore, HOF professionals, using well-established methods, need to be incorporated into the design teams with the vendor as well as with the licensee. The HOF input should inform the design, the verification and validation and the implementation of the modification itself. This process should be formally documented as part of the safety case which substantiates the modification.

Guidance relating to how these HOF reviews may be conducted is available in recognised standards and guidelines, many of which are listed in the reference section as references [3-11]. Less guidance is, however, available for incorporating HOF considerations into minor modifications, and care should be taken to ensure that both minor and temporary modifications receive appropriate

levels of HOF scrutiny. The potential for a cumulative impact of a series of minor modifications on human performance should also be considered.

The modification process should be reviewed and updated at regular intervals. The process and its implementation should be examined by the regulatory body periodically to ensure that HOFs are systematically integrated within the process.

The objective of this TOP is to present information to decision makers in the nuclear community on HOF approaches to take in dealing with facility modifications. The intended audience is primarily nuclear safety regulators and nuclear plant operators. Government authorities, industry leaders, researchers and the general public may also be interested in the views presented.

The TOP does not directly address the impact of organisational changes, which has been considered in an earlier CSNI Technical Opinion Papers No. 5 [2]. However, the potential impact of organisational changes on the reliability and efficacy of the plant modification process should not be underestimated.

1. INTRODUCTION

Nuclear plant modifications may be needed for a number of different reasons. These include physical ageing of plant systems, structures and components; obsolescence in hardware and software; feedback from operating experience; and opportunities for improved plant safety, reliability, or capability. However, experience has also shown that weaknesses in the design and/or implementation of modifications can present significant challenges to plant safety. They can also impact significantly on the commercial performance of the plant. It is important, therefore, that the plant modification process reflects recognition of the potential impact of human errors and that it incorporates suitable processes to minimise the potential for such errors.

In response to these issues, the NEA Committee on Safety of Nuclear Installations (CSNI) organised a workshop in 2003 titled "Workshop on Modifications at Nuclear Power Plants – Operating Experience, Safety Significance and Role of Human Factors" and issued afterwards a report which presented experience and practices with HOF aspects of modification process [1].

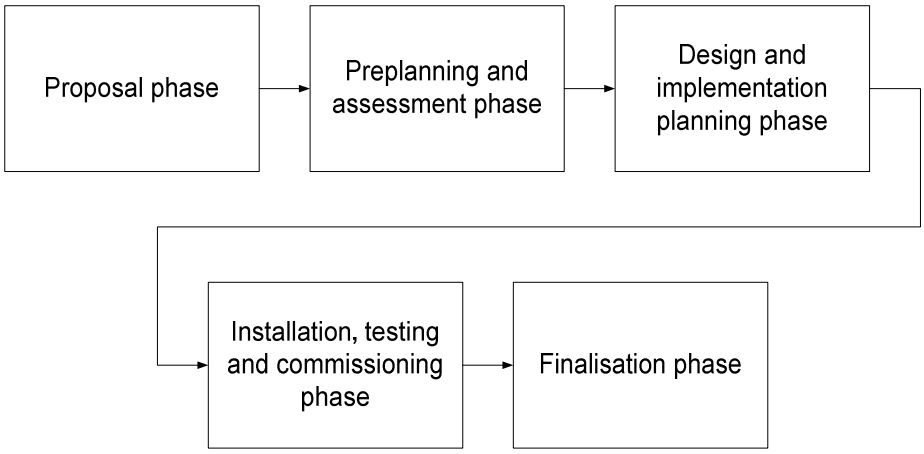
This technical opinion paper (TOP) represents the consensus of specialists in human and organisational factors (HOF) in the NEA member countries on commendable practices and approaches to dealing with nuclear plant modifications. It sets out the factors that should be considered when seeking to ensure that a plant modification process incorporates a suitable treatment of HOF. It briefly describes the elements of the plant modification process, and the way in which a consideration of HOF can be integrated within that process. The TOP does not directly address the impact of organisational changes, which has been considered in an earlier OECD/NEA publication [2]. However, the potential impact of organisational changes on the reliability and efficacy of the plant modification process should not be underestimated. Moreover, [2] noted that: "… *organisational change can be treated in much the same way as modifications to plant and equipment. The regulator may therefore require the licensee to develop a process for managing change which is akin to the process for managing plant modifications*."

The objective of this TOP is to present information to decision makers in the nuclear community on HOF approaches to take in dealing with facility modifications. The intended audience is primarily nuclear safety regulators and nuclear plant operators. Government authorities, industry leaders, researchers and the general public may also be interested in the views presented.

2. MODIFICATION PROCESSES AT NUCLEAR POWER PLANTS

Modifications at nuclear power plants should be managed in accordance with a structured process, which usually includes the phases of proposal; planning; detailed design and implementation planning; installation, testing and commissioning; and finalisation (Figure 1). The modification process should be formalised within the licensee's management system, and its design and maintenance should be subject to review in accordance with the licensee's internal arrangements. It is also usual that the modification process is reviewed by the regulator.

Figure 1. A typical plant modification process



Thorough reviews are taking place before a modification is allowed to proceed from one phase to the next. A modification process, which is divided into five phases as above may proceed as follows:

a) *Proposal phase*. Before a proposal can enter the modification process it has to be described in writing. Proposals are circulated among selected experts, including HOF professionals and future users, who give their comments to

the proposal. The work may stop here if the proposal is not considered feasible.

b) *Preplanning and assessment phase*. Proposals, together with obtained comments, are discussed and reviewed. If a proposal is considered feasible a small preplanning project may be initiated. During this phase operational experience with the old configuration should be considered in order to identify negative, but also positive characteristics of the present system(s). Special attention should be paid to human actions affected by the modification. The user's need for information and the requirements on their activities should be analysed. After a thorough review a decision to proceed with the modification may be taken.

c) *Design and implementation planning phase*. When a modification is accepted, a project is opened, resources are allocated and a time schedule is agreed on. Design work can begin and goes through phases of requirements specification, conceptual design and detailed design. Depending on the complexity of the modification it has to be considered that verification and validation[1] (V&V) may be iteratively implemented into the design phase. When a suitable design base has been established, implementation planning can be started. During this phase, HOF activities are performed with appropriate allocated resources and time depending on human actions that are impacted by the modification.

d) *Installation, testing and commissioning phase*. Before this phase can be initiated all plans for installation, testing and commissioning have to be completed. The assumption is also that necessary training has been carried out and necessary documentation has been produced. Before the actual installation commences, work instructions are written and reviewed.

e) *Finalisation phase*. This phase is intended to ensure that all open points have been taken care of, such as updating of instructions and documents, training of operators and maintainers, etc. In this phase also the lessons learned from the modification are collected including a systematic collection of operational experience during the use of the new systems (with special attention to human performance and the workload of the users). With modifications of the human system interface special attention

1. Verification in this context takes place to ensure that the designed product complies with the user's needs as well as with the technical and legal requirements described in the reference documents. Validation takes place to ensure, under representative conditions, that the performance of the product complies with the specifications and that the product effectively supports the users.

should be paid on “user friendliness”, perception and interpretation of information, error reduction (compared to the old configuration) and the detection of errors and the following recovery.

It is common for the plant modification process to require modifications to be categorised according to their potential safety significance. For example, some countries employ a comprehensive risk-informed process. A simple categorisation is to distinguish between minor, significant and major modifications based on potential safety impact and complexity of the proposed change. This categorisation may be used to determine the level of analysis and scrutiny that is given to each modification. The modification process may also include provisions to stage the introduction of the modification, with hold points and review phases being specified to reduce the likelihood of inappropriate decisions being propagated throughout the process. A staged modification process is usually employed where modifications are large, complex, or extend over protracted periods of time.

3. HUMAN AND ORGANISATIONAL FACTORS IN THE PLANT MODIFICATION PROCESS

In defining and documenting a modification process at a nuclear plant, proper consideration should be given to HOF. This means that procedures and supporting guidance should be developed to ensure that a suitable treatment of HOF is systematically incorporated into the modification process.

3.1 The need for taking human and organisational factors into account in modifications

The potential for human error or other influences on human performance can be introduced throughout the modification life cycle. The nature and impact of such errors may vary, and some of them may not be revealed during installation, testing and commissioning. The modification process should therefore include provision to include a robust, but proportionate, HOF involvement at each stage of the modification process. This involvement should influence the design and implementation of the modification, and also serve to provide both the licensee and the regulator with confidence that the modification will neither incorporate/induce errors which impact upon the safety performance of the plant, or have other adverse impacts on human performance. Successful integration of HOF within the modification process such that human capabilities and limitations are properly considered leads to the following benefits:

- Reduced likelihood of potential for human error or other human performance decrements.
- Improved awareness of, and support to, end users.
- Reduced requirements for further corrective action late in the modification process or following implementation.
- Enhanced maintainability and operational service ability of the modified system.
- Improved system reliability.

3.2 Human and organisational factors as part of an integrated modification process

In a well-designed modification process, an initial consideration of HOF should be explicitly incorporated at an early stage – for example, when the modification proposal is initially reviewed. It is important, therefore, to include a HOF capability within the plant modification team. Involving a qualified HOF specialist to carry out a screening analysis at an early stage should enable the scope and form of any subsequent HOF analysis to be identified. If the potential for, or consequence of, human error is clearly very low, the HOF contribution to the modification may be proportionately limited. If this cannot be demonstrated, more detailed HOF assessments should be carried out as part of the modification process.

The early involvement of HOF input also helps to ensure that the interactions between HOF analysts and other technical analysts are recognised, because the HOF assessments need to be informed by, and also input to, the work of other disciplines. In other words, the goal is to ensure that there is an integrated modification process that incorporates a robust but proportionate HOF capability from project initiation to completion.

3.3 Incorporating a consideration of human performance

Where it is determined that the modification may affect the way in which the plant is operated and maintained, or that the modification process itself has the potential to introduce errors, such that safety may be compromised, then it is appropriate to carry out a HOF assessment. The scope and content of that assessment will depend upon the nature of the modification. However, there are some common principles that should be considered:

- Ensure HOF analysis is integrated with other assessments.

- Open and frequent communication between designers and human factor specialists is needed to ensure that human system interactions are recognised and addressed. A timely recognition of design requirements helps in identifying possible problems to ensure that improvements can be made before equipment is selected, built or installed.

- Use of standard and up-to-date analyses and HOF methodologies.

- HOF methodologies are described in several international standards. Additional information about HOF methods can be found in various

guidelines. Examples of recommended analyses and methodologies are:

- Operating experience reviews to identify lessons learned from past experience.

- Function analysis and allocation systematically to identify functions and allocate them to humans and/or automation.

- *Task analysis* is used to identify and understand task requirements for accomplishing functions allocated to staff and to specify the users context of the product to be developed (systems, interfaces, documents, etc.). This includes:

  - The characteristics of future users (knowledge, know-how, experience, training, etc.).

  - The specified tasks (expected performances, physical and operational constraints, etc.).

  - The activities carried out (means, methods, strategies, organisation, etc. implemented for the execution of the task).

- *Human reliability analysis* is used to identify and evaluate potential human errors that may have an impact on safe plant operation, and to inform the probabilistic safety assessment (PSA).

- *Workload analysis* estimates the impact of the modification on workload in different plant operating conditions.

- *Specification of the human system interaction* required to carry out tasks is based on integrating results from human factor analyses and applying appropriate plant-specific or generic human factor design guidance.

- *Human factor verification* ensures that the equipment is compliant with common human factor guidelines.

- *Human factor validation* assesses the usability of the design with system users – for example with mock-ups, simulators or virtual reality.

- *Training needs analysis* identifies the training and competence needs associated with the modification. This should include both end-users and others such as those who install or maintain the modified plant.

- *Systematic collection of operational experience* with the new system(s) after the implementation of the modification.

- Incorporation of HOF input throughout the formal review stages of the modification.

- Application of HOF analysis to the outputs of the modification – i.e. to ensure that the modification as designed is useable and does not introduce unanticipated human error potential.

  This aspect typically involves an element of testing and, where appropriate, the use of operators. For some modifications a mock-up or simulation may be feasible. For example – in a major modification to a control room, an integrated V&V of the complete modification at a full scope, replica simulator would be desirable.

- Iterative design and active participation of end users.

  In modification projects with a major impact on existing human system interactions it is essential to involve operators and maintainers (end users) in the teams responsible for design, review, tests and V&V. End-user involvement is very important throughout the process and should be formally specified and managed. This involvement also has the benefit of helping to translate concepts and solutions into reality. Some utilities establish multi-functional groups of people with backgrounds in technical issues, operations, maintenance and human factors for the initial planning and consequent reviews of the progress of the modification project. For large modifications of the human system interaction, it is necessary to start operator training early.

- Timely HOF input to revision of procedures, and to specification of training and competence requirements.

  Throughout the modification process, the impact on procedures and training needs to be considered. Procedures and manuals need to be developed to reflect changes to the way in which the plant is operated, tested and maintained. Training and, where appropriate, the training

simulator also need to be updated to reflect these changes. Changes in instructions and the training simulator may need to be staged to ensure that proper instructional and training support can be ensured during each consecutive configuration of the plant.

- Review of changes to the design during installation.

  During installation, minor (field) changes to the design may arise, for example due to interferences with existing equipment or due to originally specified components that are no longer available. Such changes need to be reviewed to ensure they do not impact on previous HOF assessments. Minor adjustments of equipment position may cause maintenance clearance or interference issues. Depending on the HOF awareness of the modification team, a more formalised review of all field changes by an HOF expert may be prudent.

4. OBSERVATIONS FROM APPLYING THE PLANT MODIFICATION PROCESS

4.1 Minor versus major modifications

Experience shows that, in general, major modifications appear to have resulted in fewer problems than minor modifications. This seems to be due to the fact that major modifications are more likely to invoke a structured modification process, which draws in a suitable skill and knowledge base. Modifications considered as minor, because of foreseen small safety significance, may be managed with fewer financial and human resources and therefore receive less scrutiny. Although it is reasonable for assessment effort to be proportionate to risk, there remains a need to ensure that the potential impact of human error in minor modifications is considered early in order that the need for structured HOF analysis is recognised and factored into the modification process if required. Operating experience clearly shows that modifications not initially recognised as being safety significant can nonetheless introduce safety challenges. For example, the use of non-identical spare parts in a modification may lead to differences in operating or maintaining conditions. It should also be noted that an apparently minor technical modification may introduce changes that impact significantly on the operators' and maintainers' roles and the way in which they carry out other tasks.

4.2 Learning from modification-related events

It is important that nuclear plant personnel and management learn from modification-related events. Root cause analyses are typically performed after events that may have presented a safety challenge to the plant. Such analyses should identify causal factors related to deficiencies in HOF, and should also draw out whether they took place during the plant modification process. Where this is so, the analysis needs to establish whether the modification process itself has weaknesses. Experience suggests that shortcomings in the modification review stages, and communication between the parties involved, are common contributory factors. Problems in installation, testing and commissioning may similarly indicate deficiencies in the implementation planning stage.

4.3 Contracting and subcontracting

The licensee has the ultimate responsibility for the safety of the installation, which includes any work carried out on its behalf by contractors and subcontractors. The licensee therefore needs to retain an adequate intelligent customer capability in order to identify and specify the need for work, define expectations and review and accept the work of contractors. If, for example, design work supporting a plant modification is contracted out, the licensee should ensure that contractors have a suitably qualified and experienced staff and that they understand the requirements placed on work within the nuclear arena. In addition to delivery of the technical systems, expectations for incorporating HOF and user inputs within the modification process should be identified in the contract. The licensee needs to monitor the contractor's work and verify that it is being carried out as specified.

4.4 Temporary modifications

Temporary modifications can create particular problems because they may not always be treated with the same level of scrutiny and risk assessment as permanent modifications, but some may stay in place for long periods of time. Frequent use of temporary modifications should be discouraged, and may raise questions about the licensee's safety management and culture.

5. RECOMMENDATIONS

Nuclear licensees should put in place arrangements to ensure that a consideration of HOF is systematically integrated within the plant modification process. The process should be designed to support timely and effective dialogue between HOF specialists and other technical disciplines involved in the modification process. HOF professionals using accepted methods therefore need to be incorporated into the design teams. The HOF input should inform both the design and implementation of the modification itself, and should be formally documented as part of the safety case which substantiates the modification.

Guidance relating to how these HOF reviews may be conducted is available in recognised standards and guidelines. Less guidance is, however, available for incorporating HOF considerations into minor modifications, and care should be taken to ensure that both minor and temporary modifications receive appropriate levels of HOF scrutiny. The potential for a cumulative impact of a series of minor modifications on human performance should also be considered.

The modification process should be reviewed and updated at regular intervals. The process and its implementation should be examined by the regulatory body periodically to ensure that HOFs are systematically integrated within the process.

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