2015
VTT TIEDOTTEITA
VTT RESEARCH NOTES

Björn Wahlström & Jari Kettunen

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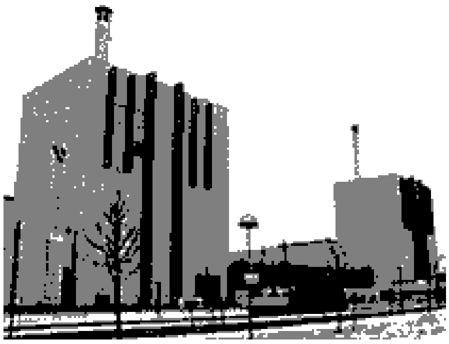

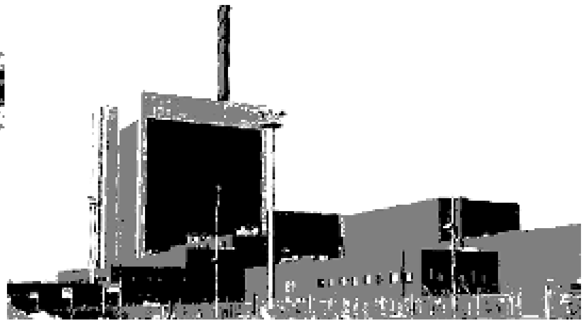

TECHNICAL RESEARCH CENTRE OF FINLAND
ESPOO 2000

VTT TIEDOTTEITA – MEDDELANDEN – RESEARCH NOTES 2015

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VTT Automation

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ISBN 951–38–5638–0 (soft back ed.)
ISSN 1235–0605 (soft back ed.)

ISBN 951–38–5642–9 (URL:http://www.inf.vtt.fi/pdf)
ISSN 1455–0865 (URL:http://www.inf.vtt.fi/pdf)

JULKAISIJA – UTGIVARE – PUBLISHER

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Technical editing Maini Manninen

Otamedia Oy, Espoo 2000

Wahlström, Björn & Kettunen, Jari. An international benchmark on safety review practices at nuclear power plants. Espoo 2000. Technical Research Centre of Finland, VTT Tiedotteita – Meddelanden – Research Notes 2015. 54 p. + app. 19 p.

Keywords nuclear power plants, benchmarking, plant modification, safety assessments, safety practices

Abstract

A benchmarking exercise on safety review practices at nuclear power plants in Finland, Sweden and the United Kingdom has been carried out. In the exercise a comparison was made between documented practices at the Forsmark, Hinkley Point A and Olkiluoto nuclear power plants. In addition a total of 28 persons at FKA, Magnox and TVO were interviewed on their views on the efficiency of the plant modification processes in the later half of 1997. One specific example of a plant modification was selected from each of the nuclear power plant sites to provide a basis for the comparison. The report gives an account of the methodology used, a description of the plant modification projects, impressions from the interviews, potential problem areas and suggestions for possible improvements.

Preface

Safe and reliable operation is of paramount importance in the nuclear power industry. Several work processes and assessment practices have been put in place to achieve that goal. Plant modification is one of the processes by which operational experience is utilised to improve the safety of the nuclear power plants. Not to introduce new safety problems all modifications have to be thoroughly analysed before their implementation. This safety review can be seen as a barrier against unsafe plant modifications. According to commonly accepted quality assurance principles, safety reviews are separated from design and operation to form an independent activity.

The present report describes a comparison of work practices, a benchmark, of safety review practices connected to plant modifications at nuclear power plants in Finland, Sweden and the United Kingdom. In the exercise documented work practices at the Forsmark, Hinkley Point A and Olkiluoto nuclear power plants were modelled and compared. One specific example of a plant modification was selected from each of the nuclear power plant sites to provide a basis for the comparison. In addition managers participating in plant modification and safety assessments were interviewed to validate the models and to collect views on possible problems in plant modification processes and safety assessments.

The report gives an account of findings from the comparison of the plant modification processes and safety assessments. The selected modification projects at FKA, Magnox and TVO are described. The report also summarises impressions from the interviews and lists potential problem areas in the safety assessment processes. Finally recommendations for implementing efficient plant modification processes and safety assessments are given, together with conclusions and suggestions for continuing the work.

Contents

Abbreviations

ALARP	As Low As Reasonable Practicable
AGR	Advanced Gas cooled Reactor, the reactor type operated by NE
Barsebäck	site in southern Sweden where two BWR units are operated by Sydkraft
CEGB	Central Electricity Generating Board, predecessor of Nuclear Electric and Magnox
ECCS	Emergency Core Cooling System
FKA	Forsmark Kraftgrupp AB, the Swedish company operating the three BWR plants at Forsmark
Forsmark	a village near to Östhammar in Sweden, site for the reactors operated by FKA
FSAR	Final Safety Analysis Report
HINA	Hinkley Point A, a reactor operated by Magnox
HSED	Health, Safety and Environment Department of Magnox
INSA	Independent Safety Assessment, a process managed by HSED
LOK	the management, organisation and quality handbook of FKA
Magnox	Magnox Electric plc, the UK company operating the Magnox reactors
MCP	Management Control Procedure, document in the structure by which safety compliance is reached at Magnox
NE	Nuclear Electric, the larger company in the UK operating nuclear reactors
NII	Nuclear Installations Inspectorate, the nuclear regulator in the UK
Olkiluoto	an island near Rauma in Finland, site for the reactors operated by TVO

Oskarshamn	a small city in Sweden, the site of three BWRs operated by OKG Aktiebolag
PWR	Pressurised Water Reactor
SKI	Swedish Nuclear Power Inspectorate, the nuclear safety regulator in Sweden
SSI	Swedish Radiological Protection Inspectorate, the regulator of radiological protection in Sweden
STUK	Finnish Centre for Radiation and Nuclear Safety, the nuclear regulator in Finland
STS	Safety Technical Specifications, a set of rules specifying a safe operational envelope of a nuclear power plant
TDP	temperature data processing system was selected as an example in the study
TVO	Teollisuuden Voima Oy, the Finnish company operating the two BWR plants at Olkiluoto
YVL	a set of nuclear safety guides issued by STUK

Glossary

It proved to be somewhat difficult to find terms and words which could be understood in the same way in all three organisations. In the report the concepts below have in the report been used in a way not entirely consistent with the use of language in each of the organisations.

design review	an internal review carried out by the design team before handing over the design for independent safety assessment
independent safety assessment	an assessment of nuclear safety which is carried out by an internal organisation which does not have functional responsibility for design and operation of the plant
inspection process	physical examinations of plant components and installations or work activities
instructions	step by step activities specified in a formal document which define how a task is to be performed
plant modification	modifications to plant, safety cases, processes, instructions, the design basis, Technical Specifications, etc.
procedure	description of tasks in a formal document which are to be performed in a process, stating responsibilities, interfaces and associated documents
safety case	an argument justifying nuclear safety in a formal document. Changes to the safety case are proposed in Category 1&2 submissions. For FKA and TVO the complete safety case was originally embodied in the FSAR at construction. The FSAR is updated after modifications are complete.

safety category	a classification assigned to plant modifications intended to indicate its importance with regard to nuclear safety, the categorisation differs slightly between FKA, Magnox and TVO, but in this report Category 1 is used to indicate the most nuclear safety significant plant modifications and Category 2 the second most.
safety review	broad range of activities such as investigations, assessments, inspections, etc. which all question the adequacy of safety

Statistics on regulatory staff in Finland, Sweden and the UK

In Finland there are 4 commercial reactors at 2 sites.	The nuclear safety department of STUK has a total of about 70 professional technical staff with a direct responsibility for inspection/ assessment activities related to these 2 sites. This number includes about 5 staff with responsibilities in radiological protection.
In Sweden there are 12 commercial reactors at 4 sites.	SKI has a total of about 110 staff of whom about 45 are professional technical staff in the nuclear safety area with a direct responsibility for inspection/ assessment activities related to these 4 sites. The Swedish Radiological Protection Inspectorate (SSI) will to this add about 5 staff.
In the UK there are 35 commercial reactors at 16 sites and 3 Magnox decommissioning sites	The NII have a total of about 200 staff of whom about 100 are professional technical staff with a direct responsibility for inspection/ assessment activities related to these 19 sites. This number includes about 10 staff with responsibilities in radiological protection.

1. Introduction

1.1 Background and motivation for the study

The study originated in an earlier benchmarking effort where the plant modification processes at Forsmark Kraftgrupp AB (FKA) in Sweden and Teollisuuden Voima Oy (TVO) were studied. In that study the plant modification processes as applied at the Forsmark and Olkiluoto sites were compared and assessed. After the completion of that project an initiative was taken by FKA to enlarge the benchmarking with another organisation and to take a closer look at safety assessments. Their specific interest was to get views on how their work processes compare to international practices. They were also interested in comparing their practices with other nuclear operators to get a feeling for the efficiency of their safety review processes and that way get suggestions for possible improvements. In the process Magnox Electric plc (Magnox) showed interest to join the common effort.

In the project it proved to be quite difficult to find appropriate words and concepts which would be understood in the same way in all three participating organisations. To ensure a consistent approach, terms have been defined in a glossary and used consistently with these meanings throughout the report even though they may have slightly different interpretations in some of the three utilities.

Plant modification is an important process at nuclear power plants. Through this process the feedback loop from the utilisation of operational experience is closed. It can, however, be difficult to introduce modifications at an operational nuclear power plant, because the effects of the modification have to be thoroughly analysed in relationship to safety requirements placed on major systems. The safety review process serves as a barrier against unsafe plant modifications. According to commonly accepted quality assurance principles, safety reviews are separated from design and they are given a large independence from the operations of the plants. This independence is important, but it has the potential to cause delays if the work is not managed efficiently.

Safety assessments are in the nuclear power companies carried out for plant modifications. Periodic Safety Reviews and other major projects are also subject to similar assessments. The auditing activities by which nuclear power plants review their own work processes can also be seen as a kind of assessment process to maintain and improve the safety of the plants. The present study aims also at forming impressions of these more general safety reviews, while maintaining the plant modification process as the most important example. The aim of the study as a whole is to identify good practices and possible improvements.

1.2 Safety assessments at nuclear power plants

The arguments by which nuclear safety is justified in a formal document is in this connection called a *safety case*. For FKA and TVO the complete safety case was originally embodied in the final safety analysis report (FSAR) at construction. At Magnox there is no similar document, but individual safety cases are written and filed separately for plant modifications. Plant modifications imply a revision of the safety case. At FKA and TVO the FSAR is updated after modifications are complete. Independent safety assessment is one of several safety reviews carried out in connection with plant modifications at nuclear power plants.

Plant modifications are often initiated either by some observed problem or by ageing and obsolescence. Modifications to safety cases can also arise because of changes in technical knowledge. Alternative solutions are sometimes proposed and their safety implications are evaluated. The proposal that is selected is further developed until enough material is available for a formal decision on how to proceed. An important ingredient in this decision will be the outcome of the independent safety assessment. The outcome is either approval which can be conditional or, occasionally, the requirement to resubmit the proposal.

Almost all work processes at nuclear power plants follow formal procedures. The formality ensures predictability, auditability and high quality of work. Often there are three stages in the design process where one person originates the design, another checks it, and the third one approves it. This is then followed by the independent safety assessment. The whole process is controlled by written procedures with clearly defined responsibilities, decision points and the production of documents. Formal audits of activities and processes provides another level of assurance that agreed work methods and safety assessment procedures are followed.

Not only modifications to hardware, but also modifications to work instructions, procedures and organisational structure can be considered in the same way as plant modifications with corresponding formal decision steps. When a plant modification is initiated it is necessary to make a proper reference to the original design and the corresponding safety case. The safety case is documented in different ways at FKA, Magnox and TVO, but it basically contains both the safety requirements and the solutions by which these requirements have been fulfilled. The safety case may, depending on the arguments, contain a large number of documents which give thorough analyses of various safety challenges. A common practice on nuclear power plants is to make the complete safety case living, i.e. to update it after each modification.

1.3 The methodology

A comparison of work practices, a benchmark, can give valuable information on the efficiency of the processes which are used. If differences in the practices are found, the question which practice is best and why can be asked. A benchmark can be carried to a comparison of resources used for various activities and thus help in identifying efficiency problems. A benchmark carries some difficulties. Practices may be difficult to compare, because they are so different. Findings may also be difficult to transfer to another cultural setting, because they might have been produced by different socio-economic environments and/ or legislative systems. There is also an inherent expectation in a comparison that one of the practices is the best, which is not necessarily true because each practice has evolved in a process of adaptation to a specific situation. Nevertheless observed differences have to be interpreted and understood in detail before conclusions can be drawn.

The used methodology consists of two parts of which one is more objective and the other more subjective. The objective part consists of the development of a formal model of utilised work processes in the way they are described in available documentation. Simplified versions of the models which have been developed as part of the study are included in Appendix 3. From the models some differences between the processes can be identified. In developing the process models it is important to note that there may be discrepancies between documented and actual processes. For completeness a model of the plant modification process as applied by STUK, the Finnish regulator, is provided in Appendix 4.

The subjective part of the benchmark builds on information collected during interviews. For the study a total of 28 persons at FKA, Magnox and TVO were interviewed on their views on the efficiency of the plant modification and safety assessment processes in their own organisations. The interviews were carried out in the mother tongue of the persons interviewed with the exception that some of the interviews at FKA and TVO were carried out in English. All interviews were taped and transcripted. The transcripts have been used to further improve an understanding of the plant processes and to collect impressions on how people view them. The questions asked at Magnox are enclosed to the report as Appendix 1. At FKA and TVO the same groups of questions were asked, but individual questions were adapted to the specific situation.

One challenge in doing a benchmark exercise is to identify the most important topics to be addressed. If one chooses to go very deeply into the activities it may involve a large effort, but a shallow study, on the other hand, is not likely to bring up very much of interest. Activities with a large influence on safety are also more interesting to investigate. For a benchmark with several organisations it is mostly necessary to involve outsiders to ensure independence in interpretations and recommendations. It is also easier to achieve the necessary openness in the interviews when they are carried out by persons from different organisation. In the formation of impressions from interviews it is necessary to understand that there always are some tensions in organisations which are handled in everyday normal working practices. The observation of such tensions is therefore not to be considered significant provided that the organisation is able to cope with them in a constructive way.

1.4 The report

This report has been written to include impressions and recommendations based both on the objective and subjective parts of the study. The report is based on an agreement between FKA, Magnox and TVO to write a single report including all major findings of the study. In addition some intermediate compilations of the interviews have been written during the exercise and they have been sent to the parties separately.

Some of the comments concerning FKA and TVO were already addressed in the report of the previous study (TAU 7005/97) and they have, when considered relevant, been repeated in this context to make the report free standing. Chapter 2 gives an account of findings from the comparison of the plant modification processes as they are documented in various documents. Chapter 3 describes the selected modification projects at FKA, Magnox and TVO together with a comparison of the projects. As noted below, these projects are selected to represent typical plant modification projects on the three stations and they were used to anchor the interviews to a specific plant modification project. Chapter 4 summarises the impressions from the interviews. Here it is important to note that some are based on statements given only by a single person and they should therefore be treated accordingly. Chapter 5 reports on potential problem areas in the safety assessment processes. The areas are intentionally selected to be generic to give some freedom in collecting findings under the headings. Chapter 6 integrates general recommendations of the study for implementing efficient plant modification and safety assessment processes. Chapter 7 gives conclusions of the study together with some thoughts for a continuation of the work.

1.5 The recommendations

The recommendations brought forward in this report are scattered through the chapters, because it was felt that they should be placed in their logical context of problem identification and analysis. The study has also been more focused on generic problems which means that some of the recommendations may appear quite general.

The study has been limited both in its scope and depth. Only a small number of persons have been interviewed and the interviews were relatively short. The findings of the study should therefore be considered with caution. Any recommendation should be carefully scrutinised before being implemented. However, the general impression is that there are some generic difficulties in safety assessments and that a careful consideration of these difficulties may bring forward proposals for better solutions. The generic problems analysed in chapter 5 can be used as a reference for special concerns and questions when plant modification and safety assessment processes are audited.

Organisations ought to have and employ their own processes for problem identification and solution. A benchmark of this kind should try to go beyond the normal routines. This means for instance that minor problems which always emerge when people with various views and personal styles are brought together should be taken care of by normal management routines. Only when these processes do not seem to function efficiently are they brought up as a finding. A benchmarking exercise should have a more strategic than immediate influence on current practices. The recommendations of chapter 6 should also be interpreted in this sense. Chapter 7 tries to summarise the impressions from the three utilities and to bring forward some strategic issues for a further consideration.

2. Processes for plant modifications and safety assessment

2.1 The regulatory framework

The largest differences between practices at FKA, Magnox and TVO are due to differences in the regulatory framework in Finland, Sweden and the UK. One may say that regulatory practices in Finland are rather prescriptive as compared with the practices in the UK where the regulator to a large extent is relying on self-regulation by the industry. The practices in Sweden are somewhere in between, but a shift towards more documented requirements have recently been initiated by the Swedish regulator SKI.

The site license gives in all three countries the basis for the operation of the plants. The site license of for the unit F3 in Forsmark consists of three pages which gives reference to earlier licenses and a condition to implement some plant modifications. These regulations and conditions include the Technical Specifications for F3, four regulatory documents and a few other conditions. Implicitly it also gives reference to the FSAR. One of the conditions in the licence is the requirement to implement a quality management system. The FKA management, organisation and quality handbook (LOK) is the response to this requirement and the LOK and all subsequent changes have been submitted to SKI for their approval.

In the UK site licenses are granted by the NII. The site license of 25.3.1996 for Hinkley Point A includes two Schedules. The first Schedule of one page gives a definition of the site and a description of the nuclear installation. Schedule 2 of 23 pages contains 35 Licence Conditions stated in brief paragraphs. Compliance with the Site Licence Condition is achieved through a suite of Management Control Procedures (MCP). There are several MCPs which are relevant to plant modifications of which the most important is MCP21, Control of modifications and experiments. The regulator has not specified a wish to formally approve the arrangements by which compliance with the majority of Licence Conditions, including MCP21, are achieved, but has the power to do so.

The present site license for TVO was given in December 1988 and is seven pages long. The most important references in the license are given to the paragraphs 55 and 81 in the nuclear power act. Paragraph 55 gives a reference to STUK and its position as a nuclear safety authority with the power to issue detailed requirements the so called YVL-guides. According to the paragraph 81 the government can issue general requirements and such requirements have been issued concerning nuclear safety, emergency preparedness and rescue service. References to the Final Safety Analysis Report (FSAR), Probabilistic Safety Analysis (PSA), Quality Assurance Program, Safety Technical Specifications, etc. are given in the decree for nuclear power which also is referenced in the site license.

In all three utilities plant modifications are categorised in one of three categories with respect to their nuclear safety significance. The basis of the categorisation is similar. At FKA the safety categorisation is defined in the FSAR for systems and components and all safety issues are related to a plant system. At Magnox the categorisation of the modifications is performed case by case. The categorisation can be challenged either internally or by the regulator. At TVO plant modifications are not categorised as such, but they will follow the categorisation of the system which is influenced by the modification. The categorisation of systems, structures and components at TVO is defined in the classification document which has been prepared in compliance with requirements from STUK. Although the systems are slightly different similar plant modifications would receive the same category at each utility.

There are marked differences between the resources of the regulators between Finland, Sweden and the UK when a comparison to the size of the nuclear power programme in the country is made. Permanent site inspectors are used in Finland, but not in Sweden nor in the UK. In Sweden and the UK all sites have dedicated inspectors, but they only spend about a quarter of their time at the site. In Sweden SKI has initiated a transfer from a detailed technical inspection to an inspection concentrating on the work processes of the licensees. In the UK the regulatory policy and structure of the site license emphasise self-regulation. The licensee is responsible for safety and must make and implement their own arrangements to comply with the requirements of the licence conditions whilst the NII have the power to intervene at their discretion.

2.2 FKA

FKA has three BWR units on the Forsmark site of which F1 and F2 are practically identical and F3 is of a newer generation. FKA is majority owned by the Vattenfall AB with 75% of the shares and other electricity producers and distributors holding the remaining 25% which according to their shares get the electricity produced at a cost basis. Vattenfall AB operated the three units until 1992 on a contractual basis. In 1992 all personnel were transferred from Vattenfall AB to the licence holding company Forsmarks Kraftgrupp AB (FKA) whose head office at the same time was moved from Stockholm to the site. An organisational change was initiated in 1994 to adapt to the need to manage the modernisation projects of all three units. FKA is using an organisation where each of the production units is a profit centre with its own commercial targets. The result of the company is made up of the result of the three production units.

At FKA a system of purchaser and supplier is used for the procurement of internal services. Typically the production department of a unit acts as a purchaser of plant modifications and the central technical department could be a supplier of investigations, design work and project management. The installation is performed by the Maintenance department of the unit concerned.

The management, organisation and quality handbook (LOK) of FKA gives a clear structure from which the corresponding procedures and instructions for plant modifications and safety assessment have been derived. The handbook is structured around requirements and responses. The handbook has been written in a process where the Managing Director and the Safety Department have specified the requirements of the activities and each unit of the company has produced a formal response describing how they are going to fulfil these requirements. The responses give reference to more detailed documents and procedures. The process for plant modifications is defined by the technical department who have issued the procedure FKA 624 which is implemented across the company. Another important document in this regard is the procedure for safety assessments FKA 824, including the independent safety assessment performed by the safety department at FKA. The procedures FKA 624 and 824 have a formal interface. All formal communications with the regulator are maintained through the safety department (FQ). The independent safety assessment is carried out when a plant modification is proposed in an investigation report (this parallels a safety submission in Magnox and the pre-inspection material of TVO). Before the decision to implement the modification is taken FQ ensures that all issues previously raised have been satisfactorily addressed. For Category 1 modifications the plant modification has to be approved by the safety committee and also by the regulator prior to implementation. The document submitted to the safety committee is the project report which is also the basis for the authority approval. Detail design and purchasing of equipment and material do normally not start until the safety committee and the authority approvals are signed off by the safety department manager as having been completed.

2.3 Magnox

Magnox Electric plc is operating 6 and decommissioning 3 nuclear power sites. The company was formed after a split of Nuclear Electric (NE) into two companies where one is operating Magnox-reactors and the other AGRs and the Sizewell B PWR. NE had similarly been formed a few years earlier in a split of the Central Electricity Generating Board (CEGB) between nuclear and conventional power. Whilst FKA and TVO have their technical and corporate services at the location of the power station, the number and geographical dispersion of Magnox plants in the UK leads to an off-site, centrally based headquarters. Of the six operational Magnox sites the nuclear power plant selected for the study was Hinkley Point A (HINA).

In spite of the large restructuring within Magnox, to date there have been only few changes affecting the procedures for plant modifications and independent safety assessment. Most of the procedures and instructions used were originally inherited from CEGB and also NE use very similar procedures and instructions. The document MCP21 actually splits into three interacting documents one for each of the interacting parties in the process, the Generation Division (i.e. the stations), the Health, Safety and Environment Division (HSED) and Technology and Central Engineering Division (TCED). In the process the station (e.g. HINA) has the role of a customer, TCED the role of a supplier of technical services and HSED the role of an independent safety assessor. The Director of HSED reports directly to the Chairman of the Board.

A plant modification is initiated by a Plant Modification Proposal (PMP) and is co-ordinated on-site by a Nominated Responsible Engineer (NRE). At HINA, all plant modifications are brought to a site based Modifications Meeting where they are discussed and assigned to a category from 1 to 3. Category 1 modifications have to be approved by the Nuclear Safety Committee and the regulator. Category 1 and 2 modifications have to go through an Independent Nuclear Safety Assessment (INSA) before they can be implemented. A Case Officer is appointed to nominate Authors and Verifiers and to set the strategy for the safety case. The Author will prepare the safety case and the Verifier will check it for technical accuracy before it is submitted to the INSA process. An INSA officer will be appointed for an assessment of the safety case when it has been prepared or earlier if notification of a case in preparation is given. All formal communication with the regulator in this process is maintained through HSED. For large projects, there will be a head document called the Paper of Principle which defines the safety principles and divides the project into stages. A number of stage submissions would be identified which comply with the identified principles and whilst they are not presented to the Committee, the Stage Submissions are subject to INSA and the agreement of the regulator if he so chooses.

The present processes for managing safety cases were brought into effect in 1990. The intent with the change from earlier practices was to make the writing and assessment of the safety cases more structured and accountable. Previously, the safety cases were produced and assessed by many persons in various positions and with various expertise which decreased the ownership of the safety case and the safety assessments.

Now training courses are given for authors and Case Officers with different levels for simple and complex cases. Magnox has recognised the efficiency benefits on getting the quality of the safety case to a good standard first time and Case Officers are encouraged to make early contacts with INSA officers to avoid fundamental omissions from the case. The use of a system of registered safety case authors is also improving the quality of safety case submissions.

2.4 TVO

TVO is owned by large industrial companies in Finland which according to their shares get the electricity produced at a cost basis. TVO is operating two identical BWRs at the Olkiluoto site and has a 45% share of a coal fired plant near Pori in Finland. The generating capacity of the two units has been upgraded once and a second major power increase is being implemented giving a 25% increase from the original design. The ongoing modernisation project is very ambitious and has absorbed many of the smaller modifications into its larger frame. The modernisation project is due to its size and importance managed with special routines, documented for example in a project handbook which complements the existing plant modification routines. The planning of the modernisation was started when it became obvious in 1993 that a fifth nuclear unit would not be built in Finland at that time.

Plant modifications at TVO are subject to rather detailed external regulation. The guide YVL 1.8 gives compelling advice on the plant modification processes and its requirements are reflected in the plant modification procedure (0-T-O-5). Other YVL-guides specify technical safety issues which have to be addressed. According to the regulatory guides TVO is obliged to inform the authority on forthcoming modifications. For Category 1 modifications a package of pre-inspection material has to be supplied to the authority before the modification can be initiated. That package corresponds to a large extent to the submission package which FKA and Magnox sends to the regulator for approval. A significant difference between STUK and the other regulators is the systematic inspection of the modifications during implementation. In the inspection process there is a considerable amount of direct contact between the regulator and the technical specialists of TVO.

The safety office of TVO has a different role than the corresponding departments at FKA and Magnox. At TVO it is a part of the Technical Department which means that it is not independent in the same way as the safety departments at FKA and Magnox. This arrangement has to be seen in relation to the much larger involvement of STUK, the Finnish regulator, in the safety assessments of plant modifications. TVO has a similar safety committee as FKA and Magnox with the difference that the Technical Director serves as chairman. The manager of the safety office serves as secretary.

TVO is to a large extent relying on external resources for design, but has still identified as a strategic issue to maintain own technical skills in selected areas. This strategy is for example reflected in the ongoing modernisation project where TVO has applied a purchasing process which is internally controlled to a large degree of detail.

2.5 A comparison of the processes

The plant modification processes at the three sites studied are very similar when it comes to Category 1 modifications. On a general level the processes go through the same stages of preliminary planning, initiation, safety review, design and procurement, implementation and testing, commissioning, and updating of documents before the project finally is completed. The processes at FKA and TVO are somewhat less structured than the process at Magnox with its decision points and clearly allocated responsibilities.

For FKA and TVO the complete safety case was originally embodied in the FSAR at construction. The FSAR has no direct corresponding document at Magnox. At Magnox the safety case is embodied in a range of documents including Category 1&2 submissions. Therefore the safety case documentation used by Magnox is more fragmented. Individual modification proposals used by FKA also includes safety arguments which are similar to the concept of the safety case used by Magnox. The pre-inspection documents which TVO sends for approval to STUK in a similar way contain the arguments by which safety can be claimed. The FSAR of FKA and TVO is updated after each modification has been implemented.

The independent safety assessment at FKA and the INSA process at Magnox is more comparable with the safety assessment which is done by STUK than the safety assessment carried out within TVO. This difference is apparently a consequence of the difference in regulatory approaches in Finland compared to the Swedish and UK systems. One may hypothesise that this absence of a strong internal safety assessment in TVO may cause difficulties in maintaining an overview of all ongoing plant modifications. Comments from TVO together with the fact that contacts to the authority are maintained directly through the technical officers tend to strengthen this interpretation.

All three companies have a nuclear safety committee. The composition of the committee and its involvement in plant modifications varies slightly between the three companies. In this connection it can be noted that the regulator attends as an observer in the safety committee meetings of FKA. Another difference is that the CEO of FKA is also the chairman of the safety committee. At Magnox the safety committee chairman is the Director of HSED and the committee includes several members from external organisations. At TVO the chairman is the Director of the technical department. At all three utilities the minutes of the safety committee meetings are sent to the regulator.

Simplified descriptions of each of the plant modification processes are given in Appendix 3.

3. The selected modification projects

3.1 Selection criteria

One modification project was selected for each of the participating organisations. The intent of selecting a project was to provide a concrete example of a plant modification and its associated safety assessment. FKA, Magnox and TVO all have a large range of plant modifications from the simple to the very complex. The number of plant modifications at a plant can typically be about one hundred during a year. Large plant modifications are considered as major projects and a few are operated in parallel each year. A major project typically ranges over several years and actual implementation on the plants may be carried out during or between several outages.

When the plant modification projects were selected the aim was to find a typical modification, not a too large nor too small a project. An additional aim was to find a project in which interaction between various design teams and skills was necessary. All the projects chosen are Category 1.

3.2 Background for the projects at FKA and TVO

On July 28, 1992, one safety valve of the main steam system opened at Barsebäck nuclear power plant in Sweden. The steam jet disintegrated coverings and insulation materials from adjacent pipelines. Parts of disintegrated mineral wool insulation was transported to the condensation pool in the reactor containment and caused clogging of the strainers for the emergency core cooling system (ECCS). Investigations of the incident revealed that the amount of disintegrated insulation material was much larger than previously calculated and that the rate at which the strainers were blocked was much higher than previously anticipated. The five oldest Swedish BWRs were ordered to be shut down until the problems were rectified. All three units in Forsmark, the unit 3 in Oskarshamn and the two units in Olkiluoto had far larger strainers and the sequence did not pose a similar risk.

Both FKA and TVO decided to install a nitrogen-based back-flushing system in order to improve the ECCS efficiency. If clogging of the strainers should occur the system can be used to clear them by blowing the blocking elements, e.g. insulation material, back to the condensation pool. If necessary, this operation can be repeated several times. The system can be operated from areas in the reactor building that are accessible during a reactor accident. The potential for clogging was also reduced to a very low probability by covering the condensation pool with special shelters and by gradually replacing the mineral wool insulation material with metal mirror insulation which is not liable to block strainers as easily as mineral wool.

3.3 FKA

FKA itself took the initiative to install a back-flushing system to all of its three units. Modifications were first carried out at units F1 and F2. Investigations showed that F3 most likely would have been able to meet the necessary safety conditions without any modifications, but FKA decided to install a back-flushing system also in F3 to keep ahead and avoid pressures from the regulator SKI. This decision gave them a possibility to proceed according to their own schedule.

The technical design of the system for F3 was somewhat different from that of F1 and F2 because at F3 the modification was assigned to a higher Safety Class than on the two other stations. The reason for the change was a slightly different safety classification for the systems in F3 and is of little practical importance, but gives an illustration of the conservatism regarding safety matters. The actual plant modification was largely based on tests and calculations that had already been conducted for units F1 and F2.

The modification project turned out to be more expensive than expected. Apart from the cost overrun, the project was carried out without any serious problems or drawbacks. The implementation was divided into two parts. The first part had to do with mechanical installations and it was accomplished by the end of the year 1993. During the second part of the project in 1994 it was made possible to operate the system from the main control room. In accordance with common practice the preliminary stages of the modification were carried out during normal operation and as little as possible was left to be performed during annual overhaul periods.

The example illustrated that deviations can occur from the plant modification instructions at FKA. According to the instructions it is possible to decide on the start of design and procurement before the safety assessment has been completed. Instruction mandates that the safety assessment is completed prior to implementation. In the chosen project installations with no engagement in existing systems took place almost five months before the formal approval from SKI was received. This was permitted by the procedure.

3.4 TVO

At TVO the installation of the backflushing system was more troublesome. After the Barsebäck incident STUK became concerned about the risk of clogging strainers. After the shutdown of five Swedish reactors STUK reacted very strongly towards TVO. In a letter calling for a reply within one working day STUK demanded that TVO investigate whether the strainers of units 1 and 2 could be blocked in a similar incident that took place at Barsebäck and to explain what kind of measures have or will be taken to ensure safety in corresponding situations.

According to TVOs viewpoint the danger of clogging strainers was minimal due to the fact that the total strainer area of about $4 \times 8{,}4\ m^2$ at both Olkiluoto 1 and 2 was much larger than that of $5 \times 1\ m^2$ at Barsebäck. The amount of mineral wool which would move to the condensation pool was also at TVO estimated to be smaller than in Barsebäck. An additional possibility was to flush strainers by feeding compressed air through the containment vessel spray system.

STUK did not agree. They argued that in an accident situation the existing system would be too slow to be used, because the containment vessel spray system did not have appropriate nozzles. They did not like the idea of feeding air into the reactor containment during accident situations. As a result, STUK required a back-flushing system which should be based on the use of nitrogen.

The modification work at TVO was carried out very rapidly which was largely necessitated by the importance that STUK attached to the modification. Further analyses were made during the whole process and different estimates on the quantity of insulation material available and needed to block the strainers were obtained. As a result of the time pressure, the project did not quite proceed according to formal instructions. Some installations were carried out without formal approval from the regulator. Looking back at the project, all parties have agreed that the whole modification process was performed within a too demanding timetable. Despite the fact that the present solution fulfils functional requirements on the system, a better solution might have been achieved if the project had been given more time for its implementation.

3.5 Magnox

The selected plant modification was the replacement of the temperature data processing (TDP) system. The TDP-system monitors and logs the reactor core graphite temperatures, the reactor gas temperatures, and the reactor pressure vessel temperatures. The system logs all thermocouples which exceed a pre-set value, generates alarms, and can also produce reactor temperatures logs and alarms on request. The existing system was approaching the end if its life and required replacement. Limited enhancements to the existing system functions were provided.

The modification was initially assigned to Category 2, but was later changed to Category 1. This change was perhaps not necessary, but reflects conservatism in assigning the category. The original design of March 1995 was changed in an addendum of June 1995. It appears that this change actually was expected almost from the beginning of the project as a result of improved technology. NII agreed in its letter of 22 December 1995 with the modification based on the supplied design material and the INSA statement. The NII chose to have no further involvement.

The modification proposal was submitted as a Paper of Principle and it was decided that the modification should be handled through five stage submissions. In the first stage submission the quality plan for the replacement was presented. The second stage submission addressed cabling and power supplies. The third stage submission covered the hardware of the new system and the fourth the software. The fifth stage submission covered testing and commissioning and it was divided in three part due to the scheduling of the work. The independent safety assessment did not reveal any difficult issues, but the implementation of the new panels in the existing control room proved to be more difficult than originally envisaged. The hardware has now been installed and the software is going through the planned development stages. The new system is being operated in parallel with the old system as part of the planned commissioning tests.

3.6 A comparison of the projects

These projects seem to fulfil the original objectives for their selection. All projects gave a good illustration of procedures used in plant modifications. The only criticism is that none of the project seems to be very typical, but one interpretation is that all projects are unique in one way or another. The three projects were rather different in the way that they were carried out. The modification of the TDP system at Magnox seems to have proceeded without haste where the TVO project was executed in a very pressing situation. The project at Forsmark falls somewhere in between. In the light of this experience one can discuss the wisdom of the regulator in exercising a very large pressure for a rapid change. At the other extreme the TDP system at Magnox seems to have taken a long time to install.

The written material available on the three projects is similar. At FKA the investigation report is well structured and it is further expanded in the project report. At Magnox the records on documents and decision points are very easy to follow. The documents from

TVO gave with some effort a possibility to assemble a very detailed record of the whole modification project.

4. Impressions from the interviews

4.1 Some general impressions

The interviewed persons had a very good overview of the plant modification and safety assessments processes. As expected there were always questions where people felt that they did not have the expertise to answer. The persons selected for the interviews complemented each other well to allow a good coverage of all issues discussed and also to get additional elucidation of some of the issues from slightly different angles.

People expressed a large interest in the study and showed a clear willingness to take in new experience and improve their own routines. Many people demonstrated a very good understanding of some of the inherent difficulties of plant modifications and safety assessment. All interviews were very open and no reluctance to discuss even difficult questions was observed.

One problem of plant modifications and safety assessment is connected to the utilisation of resources. In all three companies the impression was that people barely can keep abreast with their daily work. If this is a continuing problem it should be addressed with concern, because important long term issues tend to be prioritised down in such situations. Nuclear safety also requires the efforts of wise people who can take their time to take a look at the issues also from a more generic level.

The plant visits demonstrated that the Hinkley Point A plant is old as compared with the plants in Forsmark and Olkiluoto. However, the tidiness and order in Forsmark and Olkiluoto appear not to be a matter of age only.

4.2 FKA

The management, organisation and quality handbook (LOK) in Forsmark appears to be a living and very central document. Many references to the document were made during the interviews and the general impression is that people are satisfied with it. Forsmark has for many years used an internal purchaser - supplier system for plant modifications. The production units have the money and place orders for work to be carried out by the technical department or by external contractors. The system has brought in competition between external contractors and FKAs own organisation, but the internal organisation has an advantage in knowledge of the processes, communications and plant knowledge. There are some mixed feelings about the usefulness of purchaser - supplier system, but many of the interviewed persons agreed that it had brought in a clarity into roles and procedures.

Presently plant modifications are closely linked with strategic long term plans for a modernisation of all three plants. This puts plant modifications in a common frame and makes planning easier. An emerging insight is that modifications in I&C and man-machine interfaces can have a more profound influence on safety than previously recognised. FKA has entered an effort to write more detailed instructions for control room modifications. The general impression was that FKA has been able to collect its resources for a more proactive approach towards plant modifications and the setting of safety standards than previously.

FKA is using regular audits to assess the efficiency and quality of work carried out at various departments. It is possible to audit both a process and an organisational unit. The audits are typically carried out by a small team typically consisting of a QA person, a peer and a subject matter expert. The audits are viewed as both useful and interesting and it does not seem to be too difficult to get participants. The audits are carried out at a repeat interval between two and four years.

The interviews reported various problems both in the management of plant modifications and design reviews. Some problems are connected with the difficulty of planning with a large degree of detail several years ahead. Other problems are connected with changes in the modification process which sometimes may occur without the necessary co-ordination between organisational units. By a comparison the time pressure on the safety assessors seems to be better coped with at FKA than at Magnox and TVO.

4.3 Magnox

The process of organisational change at Magnox has been very rapid, but most people appear still to view the change as basically positive. In the CEGB era there were several independent bodies responsible for the safety assessments and the accountability was less clear. The change from CEGB to NE resulted in a better focus on nuclear power. The split between NE and Magnox resulted in a split of several nuclear sites into two different companies. With an AGR and a Magnox reactor Hinkley Point experienced such a split and, along with all other Magnox sites, had to be re-licensed. A rather complicated contract between Magnox and Nuclear Electric had to be set up to regulate the small things which formerly had been common. In spite of such difficulties, the common view is that the change from NE to Magnox resulted in a much better focus on Magnox generation and decommissioning. Overall in the split of the companies Magnox seems to have changed very little in the ways work is conducted, because common procedures were inherited from the previous organisation. Presently there is a growing divide between Magnox and NE. Regular contacts between former colleagues over the new organisational border are gradually disappearing. Some problems of maintaining specialised skills in the new situation were mentioned.

The INSA process was initiated in 1990, but it took some time to get it fully understood and accepted. The impression was that people were fairly satisfied with the INSA-process. Some further development such as training for the safety case authors were mentioned as means to make the process more efficient. There was also a clear encouragement of early contacts between the safety case author and the INSA officer to clear away simple pitfalls which at a later stage would be more costly. The INSA process appears sometimes to form a bottleneck in the plant modification process. One reason seems to be connected to resources, because with the present staff HSED can barely keep up with the incoming safety cases. The practice of stage submissions as used in the UK seems to be well functioning especially when major projects are concerned. At Magnox such are introduced with a Paper of Principle and a proposal for the stage submissions.

A significant problem is the completion of plant modifications. This is connected to the finishing of plant modifications which requires the completion of all associated instructions and documentation. As everywhere it is sometimes difficult to get engineers to document some old work when other more interesting plant modifications are pressing on. Another problem is connected to the management of old documentation and drawings which can be very difficult to verify and update.

4.4 TVO

The plant modification process at TVO seems to be less structured than at FKA and Magnox. A recognition has however to be paid to the ongoing modernisation project at TVO which places a large stress on available resources. The project itself seems to be fairly well under control and the impression may be based on other plant modification interfering with that project. At TVO it seems difficult to comply with target dates set for completion of design and safety assessment of work scheduled for the upcoming outage period. This difficulty is mainly connected to work processes at TVO, but delays caused by equipment vendors and STUK may sometimes be substantial. This difficulty is not reflected in the actual length of the outages which tends to indicate that people put in efforts which are beyond what originally was planned for the work. Several of the persons interviewed made an observation that it is difficult to get an overview of the planned loading of resources. At TVO it is sometimes felt that the overview of plant modifications is lost, because they are broken down into relatively small parts.

The presence of STUK on the plant site is far larger than what is generally experienced both at Forsmark and Hinkley Point. One inspector is located on the site continuously and during outages there could be more than ten inspectors on the site at the same time. STUK inspectors are also engaged in the back end of the plant modifications in such a way that they inspect the finalisation of the work. The communication process regarding plant modifications puts its own influence on plant modifications and safety assessment at TVO. Still the general impression is that there are not many problems in the communication between STUK and TVO. This generally positive picture is however somewhat offset by a present disagreement on how to handle programmable automation in a safety case.

4.5 The safety assessment process

On a general level there do not seem to be any major problems involved with the safety assessments of plant modifications. There was a large consensus among all persons interviewed that it is very unlikely that significant safety threats do slip through the safety assessment process. Some of the interviewed persons at FKA thought that modifications which do not require detailed safety consideration should nevertheless get a proper design review before their implementation.

Rather few disagreements in principle seem to emerge between safety case authors/ designers on one hand and safety assessors on the other. There is a common acceptance that the review process improves the overall quality of the plant modifications. There are often discussions on detailed technical matters, especially when judgement is involved on what is good enough. In principle such disagreements may be resolved by transferring the issue to a higher management level, but in practice designers and assessors almost always agree on some feasible solution. Sometimes single individuals may be tempted to stress the validity of their own view by a reference to the authority, even if such a reference is not relevant. However the impression is that this happens very rarely.

The quality of the safety case are reviewed both at FKA and Magnox. If it is considered to be below a certain minimum standard the safety case is simply returned to its author to be rewritten. This occurs in less than 10% of the cases.

The general impression is that safety assessors are never constrained from expressing uncomfortable views. Sometimes, but especially when projects are running late, a severe pressure is mounted to get a specific assessment completed. The impression is that the safety assessors will not succumb to such pressures by making shortcuts, but rather make their concerns and the basis of acceptance more clear. It is important that significant safety issues are addressed in a lucid manner in the safety case submissions, because that will make the assessments easier and more efficient. The independence of the safety assessment process seems at least at FKA and Magnox to be ensured with good margin.

There is a strong awareness especially in Magnox that the signing of the INSA-statement involves a heavy personal responsibility. At FKA the assessments are given a reconsideration by the signature of the superior of the responsible assessor. If time pressures increase in the process the efficiency of the barrier function of the safety assessment may decrease. Some indications were observed at TVO that this may occur. There is an understanding of the dangers involved if a list of signatures in a safety review gets very long.

4.6 Communication between designers and safety assessors

There seems to be a very good understanding in all three companies that safety assessments are important. There is also a clear recognition of the different roles in the process. Sometimes it seems difficult to convey the reasons for the time spent during safety assessment. For Magnox the safety assessment with its place towards the end in the handling of a plant modification makes it particularly vulnerable to earlier slips in the time schedule.

At FKA safety assessors do not have an early involvement with the designers. At TVO the safety assessors indicated a wish for an earlier involvement in the process. An early involvement may according to Magnox help in avoiding major pitfalls in the design / safety case and to consider safety requirements in a balanced manner. When a safety case has been rejected in the assessment process it may happen that the designers ask the safety assessors to provide an acceptable alternative. When this question occurs the safety assessors at FKA and Magnox deny to answer it together with clear signals that the question is considered inappropriate.

The writing of a good safety case requires a good understanding of the plant and its basic safety features. There are large variations of how safety arguments are developed. One complaint is that the descriptions can be unnecessarily technical, but do not contain the arguments necessary to make an adequate nuclear safety case. Safety assessors should approach their task with impartiality, but quality expectations may still influence the effort spent on the assessment. Problems were mentioned both at FKA and TVO in having enough project managers for the plant modification projects who have a good understanding of the basic safety principles of the plant.

There are personal styles in writing safety submissions and doing independent safety assessments. There are also differences in communication styles and reference was sometimes made to outspoken persons on either side which needed special considerations to avoid misunderstandings. At FKA reference was also made to the fact that the designers as a rule are younger and not as experienced as the people doing the design reviews. An awareness of these issues can help in avoiding unnecessary social stress within the organisation.

4.7 Work management

The time pressure on the staff can be sensed not only in the three companies visited, but more broadly in the whole nuclear community. Reasons for the time pressure can be found in the pressures of a competitive market which call for achieving more with less resources. Ageing stations require more efforts for refurbishment and have an increasing gap to close to meet modern standards. These efforts have to be integrated in the operation with the restriction that some of the work can be done only during plant outages. This implies that work associated with planning and co-ordination of various activities becomes large and complex.

There do not seem to be good tools available for planning and management of resources utilisation. It seems also to be difficult to track all activities which are going on at the same time. TVO is using a computerised system for project management which is helpful in scheduling tasks for different outages. FKA has investigated the benefit of tools for resource planning, but no decisions have yet been made. The major problem in bringing in formal planning tools is the difficulty of providing realistic estimates of resources needed for various tasks. Estimates tend often to be overly optimistic with the consequence that time pressures will increase towards the end of the project.

Some problems with the co-ordination of various tasks during one outage or as a part of one plant modification were sited during the interviews. At FKA a slip in the work planning caused problems in completing certain modifications on time with the consequence that the whole outage time schedule was put in jeopardy. At TVO the lack of an overview of scheduled work was said to cause problems for the resource planning.

A problem mentioned at FKA is connected with the late arrival of orders for modifications which tend to cause difficulties with the resource reservations. Negotiations on scope and time-schedule for plant modifications therefore tend to be unrealistic and there is a risk of overbooking. If initial non-binding reservations from the production to the technical departments could be made it may be possible to reach a better predictability. Anyhow it seems that the problem can be solved by a better communication between the departments involved.

All three companies use external contractors especially during the outage period. The amount of outsiders in Forsmark and Olkiluoto may even approach a thousand persons. Magnox employs a number of former staff on a contractual basis. The utilisation of consultants and subcontractors can serve to cut peaks in work demand, but may introduce other problems. Outsiders will require more direction in the work than own staff and they are not always aware of company priorities and work practices. Investment in skill development of outsiders do not have the same later accessibility as for own personnel. An identification of necessary core competencies may help in this respect.

4.8 Audits and reviews

All three companies perform regular audits and reviews of their processes. The audits differ somewhat in their details, but aim in general to ensure that procedures are followed and to bring feedback for the development of the processes. There was a large degree of consensus with respect to the importance to carry out such audits. In FKA there is no difficulty in collecting teams for the audits as they are seen as valuable both for the unit having the audit and for those who are performing it.

Feedback from the executed plant modification projects is collected, but in a less systematic manner. Plant modifications intended to be carried out on two units at separated instances of time are typically planned to build on experience obtained from the first project. Some of the feedback on plant modifications is collected at the review meetings held after each outage. Many of the interviewed seem however to agree on that there still are many possibilities to make the feedback from earlier plant modifications more efficient. At FKA it was suggested that feedback from the plant modifications should be collected when they have been in operation for some time.

4.9 Conflicts between safety and economy

Conflicts between safety and economy are sometimes thought to cause problems in plant operation. The economics of keeping the plants in operation creates a clear pressure for completing plant modifications in time. The costs of a single plant modification project are often negligible as compared with the costs of an extended outage. The interviews brought no impression of costs to be a restrictive component when important plant modifications have to be decided on. Safety assessors of Magnox said explicitly that they did not look at the economics at all, but an argument could sometimes develop whether or not the proposed plant modification was enough with respect to its improvement of plant safety.

The discussion on what is good enough takes sometimes a direction related to costs. It is evident that a resolution of such question will require value judgements. Magnox has formulated an ALARP policy which is applied for handling risk in a tolerable region. This principle provides guidance in a discussion on what is good enough. TVO is similarly using the PSA as a tool for evaluating safety impacts of plant modifications.

5. Potential problem areas

5.1 Management of plant modifications

Plant modifications are an important part in closing the loop from feedback of experiences to actual safety improvements. Some plant modifications are also made in response to more stringent safety requirements. Plant modifications are an important response to ageing and obsolescence. However, it is important to recognise that the introduction of a modification represents a change from something established and therefore potentially is a risk in itself. A plant modification has to be based on current safety reasoning, but this reasoning may sometimes be difficult to make explicit enough.

The implementation of a plant modification will often be carried out in stages. Some early preparation may be possible to carry out during power operation, but the major part typically has to be done during a plant outage. Each of the implementation phases should be controlled by instructions and procedures which should be as clear as possible, i.e. contain definitions of roles, decision points, tests and inspections, documents, etc. When new systems are taken into operation their validation may require some parallel operation of the old and new construction. When that is necessary the complexity in ensuring that all necessary safety precautions are made will be further increased. Finally plant modifications should be brought into routine operation after corresponding modifications in instructions, documentation and training programmes.

Plant managers must have a good overview of modifications in progress to avoid uncoordinated activities at different places and times in the plant. Various phases in the design and safety review have to be co-ordinated with formal decision points. Responsible persons should have a clear understanding of applied processes and actual work going on. Time schedules add on an extra twist with critical paths and dependencies between tasks. The emerging picture can be very complex and it may be difficult to sort out relevant issues one at a time.

In approaching a solution to the management of plant modifications it is important to ensure that all aspects are accounted for in a balanced way. Safety issues do not seem to pose major problems, operability issues may sometimes not be considered to the degree they deserve, but maintainability issues are often not given a proper attention.

When a power utility operates several nuclear power plants of a similar design there is an incentive to operate them within the same framework. At Magnox there have been significant changes from earlier days when the CEGB organisation was nationally regionalised and power plants were fairly autonomous. When this is the case there is a risk that similar plants adopt different approaches in operations and plant modifications.

Such a variety is difficult to maintain and there are clear incentives for finding generic solutions. At FKA the response to these challenges has been to utilise a system assigning functional responsibilities for joint company processes. Such common approaches can also be supported by benchmarking between plants and units.

5.2 Managing safety assessments

Safety assessment is an integrated activity connected to various modification processes. To be efficient, safety assessment should be given a sufficient integrity to pose difficult questions. This is regularly ensured by making safety assessors organisationally independent from design and the line organisation. It is not a simple question to specify the necessary degree of independence by which this integrity can be ensured. The three solutions selected by FKA, Magnox and TVO reflect three different views and historical traditions.

Comments from the interviews tend to suggest that individuals could contribute to some projects both as designers and on other projects as reviewers provided that they do not review their own work. This practice is applied to some extent at Magnox, where people from the technical department can serve as designers and as subject matter experts in support of the safety assessors on unrelated cases. The situation of Magnox with a centralised organisation and with the nuclear sites placed elsewhere tend also to make this practice easier to manage. In the organisation of Magnox it is still important that the HSED is separated from plant operations and from the technical department.

Independent safety assessment has to rely on personal commitment and responsibility. The safety assessor is supposed to confirm his belief in the completeness and correctness of the assessment with his signature. That should imply a very careful consideration of the whole issue and a tacit check that no corners have been cut. It may be wise with some regularity to check that this responsibility is understood and accepted.

The discipline of expressing safety arguments explicitly with a clear reference to requirements and basic safety principles of the plant has a potential to lead to a more efficient safety assessment process. Comments from Magnox on the need to invest in writing good safety cases tend to strengthen this interpretation.

5.3 Writing and maintaining procedures

Written procedures and instructions form the backbone for activities and processes at nuclear power plants. Good procedures and instructions are a prerequisite for a high repeatability and quality in all work processes. Procedures should strike a correct balance between readability, comprehensiveness and length to gain acceptability by their users in the day-to-day work. Both technical and administrative considerations should be included. Each organisational unit responsible for some specific activity should have its own procedures and instructions and the interfaces between various procedures should be such that they work together as an entirety. It is also important to provide an overview of available procedures and instructions. Finally the procedures and instructions should be subject to periodic reviews to incorporate operational experience and check their compatibility with safety case requirements.

It is usual for organisational units to be given the responsibility to write their own instructions. This is certainly correct, but it introduces some problems which have to be addressed for a successful end-product. Instructions should fit into a general structure which means that clear guidelines should be available for how to write them. There might also be a need to ensure that two related instructions actually work together. When an organisational unit has written its own instructions they are often enacted from memory which may introduce problems when instructions are changed.

Some observations from the interviews pointed to the generic problem of managing written procedures and instructions. At FKA a change of the procedure covering plant modifications of one department had been made which should have initiated a change in the corresponding procedure for another department. At Magnox some small inconsistencies between the three versions of the plant modification procedures were observed. The MCP structure used at Magnox gives a rather complex hierarchical structure and it seems to be difficult to make changes and amendments. In the material from TVO some discrepancies between the quality handbook and the plant modification procedure were found.

5.4 Coping with time pressures

Time pressures are common at all three nuclear utilities. Time pressures can emerge as a result of unrealistic ambitions, under-staffing or inefficient management. Time pressures mount a serious safety threat, because they can decrease the work quality of several activities simultaneously. Time pressures may also introduce unexpected re-prioritisation of activities, because those who have the loudest voice are more likely to get their service first.

Responses to time pressures can be found in setting realistic goals, allocating more resources and in better planning. The major cause for the time pressures at FKA and TVO seems to be connected to a high ambition level. At Magnox the time pressures seems to be more related to downsizing and adaptation to a competitive electricity market. Resources should be reserved at a level to ensure that all activities can be carried out with a reasonable effort. If this is not the case there is no slack in the resources to make it possible to cope with unexpected events. It is often wise to make a specific allocation of resources on long-term activities and training, because they tend to be neglected when work starts to pile up. To obtain reliable estimates for resources needed for some specific job there is often a need for some inter-calibration of various estimates given. Effective planning can also to some extent avoid problems which may otherwise have a domino-effect.

When time pressures are building up, it may sometimes be wise to admit that ambitions were set too high and then simply take more time. This decision may however be very difficult in practice, because certain commitments have been made, materials have been ordered and resources reserved. The interviews gave a few examples of problems with time pressures and late changes in plans. At FKA in preparing for one larger plant modification changes were introduced in the man-machine interface even after the order to the technical department had been placed which caused several difficulties during the outage. At TVO the design installation of the backflushing system for the strainers were hampered by the pressure exercised by the authority.

Time pressures are not completely negative as long they are manageable. People tend to set ambitious goals and without the time pressures of a delivery date the work often goes on very long. Many of the persons interviewed actually stated that people often work better under a reasonable level of stress. Some others thought that their organisation is better in responding to a crisis than carrying out routine type work. It is evident that both too little and too much is not good in this respect

5.5 Plant documentation

Plant documentation such as drawings, component lists, cabling routes, maintenance manuals, procedures, work instructions, etc. has a crucial role in many activities. For plant modifications the documentation forms the basis of the work. Unfortunately the quality of plant documentation is sometimes discouragingly low which means that a considerable work has to be spent in re-establishing the design base and verifying old documentation. According to a comment from Magnox the old drawings should be validated where possible before they are used in the design phase of the plant modification. It is apparent that this problem is larger at Magnox plants than at FKA and TVO.

Another difficulty connected to documentation is to ensure that the modifications are properly brought into drawings, system descriptions and instructions. All three companies have formal systems to ensure that a modification is not removed from the activity list before the documentation has been updated. Sometimes it can be very difficult to identify all documents in need of updating. It also seems to be difficult to motivate engineers to do such updates. Magnox for instance had collected a relatively large number of plant modifications not fully completed. These depend in many cases on some remaining problem with the documentation. This unwillingness may partly be attributed to time pressures in the work, but is also likely to include problems of attitude.

There is also a problem of maintaining a complete and detailed documentation of the safety case for various systems, especially when a large number of modifications have been made. FKA has met this challenge by updating the FSAR continuously and maintaining three complete set of reference documents one in the technical department, one in the unit in consideration and one in the safety department. Magnox has created a system of reference called the Schedule of Reference Safety Statements which gives an index to various documents which makes it possible to collect the information on single systems when needed. TVO has similarly to FKA invested considerable efforts to maintain both the FSAR and the PSA as living documents.

All three utilities have taken steps to ensure a better availability, understanding and completeness of the safety principles of the plants. FKA has initiated a project which aims for a reconstitution of the design base including basic safety principles which ABB Atom used in their design for the two oldest units in Forsmark. Magnox has been creating a safety review guidebook applicable for gas cooled reactors. The modernisation project at TVO includes a complete revision of the FSAR.

A solution at least to some of the problems with documentation is to use modern information technology. New tools such as hypertext information networks may create better possibilities for linking documentation together and to generate a better traceability between various parts of one document. Revisions of various documents would also be easier to keep track of in such a system. By creating a better ownership for the documentation some improvements may also be reached. FKA has investigated possibilities to move towards computerised documentation systems. TVO has created an application of their safety technical specifications (STS) based on hypertext.

5.6 Fostering attitudes towards safety

Attitudes have an important position in maintaining safety. The interviews did not give any indication of deficiencies in this respect. The persons interviewed were also convinced that personnel in general are very safety conscious. Some concern was however expressed that contractors may not always adhere to the same high standards. A response to this concern has been to give contractors special safety training.

Training of new persons employed for the first time in the nuclear industry is very important. Unfortunately the industry has not had the possibility to employ very many new persons for the last ten years. This may in some years may emerge as problems with the age structure. FKA is an exception in this respect where a systematic investment in apprentice engineers has showed to be beneficial. FKA also uses a system with godfathers and mentors to support new persons technically and socially in their careers.

A willingness to report also minor deviations from expected quality standards gives a confirmation that safety attitudes are on a high level. Some concerns was expressed at Magnox that such reports indicated a relatively high amount of human errors, but there is still a strong support for the "no-blame" culture.

5.7 Regulatory attitudes

The interaction between the utility and the regulator influences the processes for plant modifications and safety assessments in several ways. Firstly the legislative framework together with the site license defines the environment into which other considerations should be adapted. On the next level guidelines and recommendations from the regulator form a second layer of interaction. A third level is through normal day to day interaction through the regulators site inspection process or through the safety departments. It is evident that issues always emerge where the views of the utility and the regulator differ. Such issues should as far as possible be handled on a technical level avoiding reference to persons. Only then is it possible to maintain open and trustful attitudes. All three companies expressed as their policy to be as open as possible towards the regulator. TVO for instance provided access to the plant computer network with its information to the STUK resident inspector.

The regulator should also be aware of possible unwanted side-effects of overbearing intervention and take responsibility for them. Disagreements for instance on some detail may stall even an important plant modification for a considerable time. High pressure to resolve some specific issue can force the utility to drop other important tasks. The regulator should therefore use his power very sparingly and only in those cases where it is really needed. Similarly it is beneficial for the utility to initiate necessary safety improvements voluntarily. Examples of modifications undertaken to keep the regulator happy were mentioned. Both the regulator and the utility have an important task in creating openness and trust in their mutual communication.

5.8 Strategic planning of activities

Strategic planning, including the definition of ambitions and the setting of goals and priorities which take realistic account of available resources, is an important first step towards addressing many of the problems indicated above. Planning has to include a recognition of uncertainties and a preparation for contingencies. The difficulty of strategic planning lies in making predictions which are good enough to support a insightful selection between available options. Strategic planning involves a setting of priorities where goals are conflicting. Strategic planning also involves the definition of a long term plan which makes it easier to identify the need for resources in the future. The strategic planing should especially be concerned with the identification of issues where a change in scope and direction of activities might be necessary. A proper allocation of resources between various activities can actually improve plant safety without additional investments.

Strategic decisions involve visions which often are difficult to validate and their implementation require power and persistence. Major organisational changes can shift the location of power and thus influence the interactions between organisational units with subtle effects. The ALARP principle can provide support for major technical decisions on safety targets and costs in the consideration of a projected lifetime for the plant. A long term strive for operational excellence is possible only if managers have both insight and wisdom to be cautious and courageous at the same time.

Strategic planning should involve both top down and bottom up processes to ensure that goals are communicated through the organisation and that a realistic assessment of available resources is made. It is often too easy for the management to put on additional pressures for an increased efficiency and similarly for the executing parts of the organisation to be too optimistic with respect to efforts needed. If the communication channels between management and those who implement policies and decisions become impaired serious problems may emerge.

6. A systems view on plant modifications and safety assessments

6.1 Plant modifications

Many of the plant modifications are placed in a longer strategic perspective of undisturbed operation for even tens of years into the future. The long perspective makes it however difficult to argue for the most suitable time for a specific modification, which means that schedules contain components of vision and ambition. When strategic plans are brought to the short term planning the resource allocation becomes more concrete. In the planning it is necessary to leave some slack in the resource planning to be able to cope with contingencies without a too large impact on other activities. It is also necessary to take into account the special competency which is needed in certain phases of plant modifications projects.

Various ways to look at plant modifications sorted for instance with respect to revisions, rooms and cubicles, responsibility, implementation stage, etc. can be of help during resource planning. It is necessary to co-ordinate multiple tasks simultaneously and manage their relationships and allocation in time. External resources can balance peaks in the demand of resources, but tasks to be carried out by outsiders have to be well defined. This means that the actual relief for the organisation may be far smaller than the effort bought in.

Plant modifications as a part of the entire system may require its own considerations. Only by ensuring that both the systems and their interactions have been considered in enough detail is it possible to ensure that no unexpected safety threats will appear.

Collecting experience and learning from earlier plant modifications is an important part in a continuing improvement of work processes. Audits and reviews of the plant modification process and their reflection in procedures and practices is another part in ensuring nuclear safety.

6.2 Building systems for safety assessments

The safety assessment processes should be managed in the same way as other important processes. A long term consideration should steer the development and adjustments to be based on experience collected from earlier assessments. The safety assessment should be independent of design and economic considerations, but it may prove impractical to duplicate some specialised competency. An early involvement of the assessor may therefore be necessary and acceptable provided that it is managed properly. This involvement can support a broad consideration of safety aspects, but it may create bindings impairing the independence of the safety assessment. If this risk is understood it can most likely be avoided.

A personal responsibility is a crucial component in maintaining quality of the safety assessments. Maintaining the competency of safety assessors is important and it may be supported by job rotation and participation in reviews of various safety activities.

A balance has to be found between safety assessments at an early instant where no details are available and at later instant when details are available, but it would be costly to undo major flaws in the design. Safety requirements and the burden of proof have increased over the years and this implies that the quality of the safety arguments and their presentation have to improve. The clear division of responsibility between the author of the safety case and the independent safety assessor as utilised by Magnox makes the process transparent and easy to review.

It is necessary to break up major projects into smaller parts which are easier to manage, but this may introduce other problems. It is more difficult to maintain an overview when there are many small interrelated parts of a project. A tacit coupling between project parts may also create a pressure for accepting later parts.

6.3 Ensuring quality of safety assessments

There is a dependency between the quality of the safety case and the efficiency of the safety assessment. If the original safety arguments are easy to understand and complete, it is more likely that the safety assessment will be efficient. A safety case which is well structured and explains the safety functionality of systems rather than the technical details is more straightforward to assess. A traceability within the safety case which helps to connect safety requirements with technical solutions is also valuable. The availability of clear norms for what can be considered acceptable and what cannot, makes it also easier to write the safety case and to carry out the safety assessment.

There are both benefits and dangers of involving several persons in the safety assessment. Several persons can look on the safety case from different angles and thereby contribute to a closer scrutinisation. On the other hand the personal responsibility may be diluted if several persons participate without a clear allocation of responsibility.

The quality of work will always to some extent depend on the individual. Still it is necessary to create a system in which such a dependence can be decreased. Different safety assessors use different assessment styles and the styles may be illustrated in the training to make it easier for the assessors to adapt to the task. Training of safety assessors is important, but the dilemma often is to create inspiring courses for skilled assessors. One possibility is to use job rotation to make it possible for the assessors to see various aspects of the safety work. International benchmarks can be a valuable part of such training.

Safety assessments are one part of the efforts by which safety of plant modifications are ensured. There should be a balance between the preparatory and the assessment parts of plant modifications. In building safety into the plant modifications enough resources should be allocated to the early parts of the safety considerations to establish a basis for design and construction. The belief in the correctness of the design builds also on the used methods and tools during the design process. Correspondingly the effort for an in depth assessment can be decreased if efficient tools are available. If the use of some specific assessment tool is expected to be large the spending for its development may be motivated.

6.4 A formalisation of processes

Work processes need a certain formalisation to ensure quality and repeatability. The formalisation can also improve efficiency in the processes by providing clear script for how certain tasks should be carried out. The formalisation can be seen as the assignment of roles and responsibilities to well defined tasks and positions. The formalisation should include the definition of clear decision points and specified documents to be produced in the processes. The selection between alternatives should be based on an assessment of an overall efficiency of the processes. There should be a close link between the development of work processes the more general company business processes to set a practical level of monitoring and reporting.

In the formalisation of work processes a proper level of comprehensiveness should be found. The procedures and instructions should be correct and well written and they should be adapted to the process they are supposed to control. One of the engineers at TVO noted that instructions should be followed, but you should always apply common sense. This statement illustrates an important truth that instructions may contain errors, but it is not in agreement with good safety culture to allow interpretations. At FKA it was clearly stated that instructions are followed literally and changed when this is not possible. Instructions can allow for some flexibility, because very formal routines may introduce difficulties in utilising the best expertise for some specific task. Very formalised routines may also be a barrier for organisational learning. In the routines there should always be room for solving unexpected problems.

In building formal work processes it is also necessary to create corresponding processes for their management. This means that an ownership of the processes in a broad sense has to be allocated and anchored in the organisation. The management, organisation and quality handbook of FKA, which is structured into requirements and responses provides one example of how this organisational anchoring can be achieved. In planning for the work processes it is sometimes beneficial to set up formal models of them, because this makes their structure transparent and easier to discuss.

6.5 Continuous learning

Continuous learning is often given as the secret behind a good safety record. A systematic collection of operational experience which is utilised to improve work processes is a necessary component of good performance. Setting and monitoring quality standards for various work processes which contribute to nuclear safety is an important management tool. Comparisons and benchmarks can provide important insights in the development of work processes.

Feedback is important for the learning process. All organisations have systems to collect data on their performance. Such data is important, but may not be enough for all purposes. Sometimes it may be necessary to get data on attitudes, fears, aspirations, problems, etc. One way in which this information can be obtained is through interviews and questionnaires. Feedback on performance is also relatively short-lived. One problem is often to find the necessary time to analyse collected data in depth to generate the necessary understanding for strategic decisions to be made.

It is necessary to allocate enough resources on this learning. Only in that way is it possible to maintain a proactive approach in work processes. It is necessary to identify weak signals of emerging problems and to initiate corrective actions. The organisational and management culture should support a vision towards the future. Components in this long term strategy are also to maintain a sound age structure and use job rotation for a continued development of the personnel. One dilemma with high performance organisations is that when few deviations occur the personnel have very few opportunities to learn from actual experience. On the other hand the nuclear industry cannot afford a trial-and-error approach, but has to rely on analytical methods for achieving sufficient safety.

7. Conclusions

7.1 Impressions from the three utilities

At FKA a well structured plant modification and safety assessment process is employed. The management, organisation and quality handbook (LOK) is an asset in its structure and the way it has become accepted and used. The regular audits and reviews of various work processes at FKA have proved very useful. Some doubts may however be expressed to the apparent conviction at FKA that their own processes are the best. The role and task of the safety department is accepted, but it seems that it is not completely understood in all parts of the organisation. At FKA there is a belief in the formal systems which carry a danger that the overview is lost in the handling of details. It seems necessary to strengthen the technical department at FKA to make it possible for them to take a responsibility for long term development of the plant. There are difficulties in planning of the allocation resources for plant modification projects. There seem to have been some minor slips in the updating of interconnected procedures for the handling of plant modifications.

Magnox has a very well structured plant modification and independent safety assessment process. The process is supported by clearly defined responsibilities, documents and decision points. Safety assessors have a clear personal responsibility in the INSA process. Magnox has addressed the training of safety case officers, authors and assessors to make the process efficient. Magnox is fighting against shrinking resources and degrading competency which is connected to down-sizing and early retirement. At Magnox it appears to be markedly more difficult to plan into the future for the independent safety assessments, because of a comparatively large number of unexpected and urgent assignments. Some plant modifications seem to proceed with far less urgency than at FKA and TVO. The way safety case documentation is managed at Magnox is more fragmented than at FKA and TVO which use a living FSAR. The procedures used in the MCPs are somewhat difficult to comprehend and some small inconsistencies were found in the interfaces between interconnected procedures. There seems to be a backlog in uncompleted plant modifications which would be important to clear.

TVO has a technical orientation and focus on efficiency which is reflected in good availability figures and short outages. The ongoing modernisation project is very ambitious with many safety improvements in addition to the increased output power. TVO employs a system with careful planning of all plant modifications in a long term plan which makes their implementation very efficient. The plant modification process is however not as well structured as at FKA and Magnox. The position of the quality handbook and its relationships to the plant modification instruction are somewhat unclear. At TVO there are diverging views on the content and efficiency of audits. The plant modification process is defined in compliance with regulation issued by STUK and it would be advisable to initiate a dialogue with the regulator on how the process could be restructured. In the plant modification process better commitment to time tables seem to be needed. In finalising a plant modification project it is advisable to have a formal modification hand over procedure like for instance at FKA.

7.2 Some additional observations

All three nuclear utilities demonstrated a very clear commitment to safety. They were also eager to improve their work processes. The importance of an efficient feedback of experience was well understood. The staff at all three utilities suffered under a heavy work load which reflect problems within the nuclear industry which is connected to increasing demands on efficiency. FKA, Magnox and TVO have all in their own ways solved the problem of ensuring a sufficient safety in the design and assessment processes. The staff of all three utilities seem to be well aware of the inherent challenges in completing a safe design, in assessing the validity of the safety case and in documenting it properly. All three utilities are fighting hard for maintaining competency in an environment characterised by nuclear opposition and down-sizing. In the light of the present study it seems to be well advisable to continue with benchmarking efforts. Tools for resource planning and management seem to be important for making plant modification processes more efficient. Finally it seems necessary to create better systems for managing plant documentation.

The purchaser and supplier system which is used by FKA differs from the system used at Magnox and TVO. A shift in power from the technical department to the production department was experienced when the system was adopted at FKA. The good thing with the system is that production aspects are prioritised and closer connections to needs are created. An ownership of the plant modification is also created at the production department. The system makes is possible to obtain short response times and immediate feedback to the project. There are however also drawbacks with the system which have to be understood and compensated for. Among them are the fact that the production department may not have the skill and vision to decide on the plant modifications to purchase. In buying only turn-key projects the benefit of skill development will be reduced. Finally money may get a too important position in selecting the plant modifications to be implemented.

FKA and Magnox has a clear separation of the safety department from the plant modification processes. TVO has a more integrated process where the safety office has an important position, but is not separated from the design process. The benefit of a separation is that independence gives a clearer and more efficient safety barrier. Safety thinking is also made more explicit and the regulator can gain confidence in the process. A separation may however also postpone a thorough discussion of safety issues in the process with a corresponding risk of late changes. The independence may create a need for some duplication of resources. The separation may also create longer lead times and bureaucracy in the work processes.

The living safety case as documented in the FSAR is an asset at FKA and TVO. The system of maintaining plant safety cases used by Magnox gives a way of keeping reference to the safety cases, but does not give a similar ease of access to the basic safety requirements of the plant. The requirements as documented in the YVL-guides of STUK give a good basis for the safety reviews carried out at TVO. The safety review guidebook for gas cooled reactors developed at Magnox provide similar, but more restricted guidelines for writing and assessing safety cases.

Benchmarking has in the study showed to be a good method to assess work processes. It brings insights into other ways of thinking and therefore also in the generic components of nuclear safety. It helps in identifying strengths and weaknesses of own work processes for their further improvement. A difficulty is however that practices sometimes are difficult to compare, because they also include cultural components. It is difficult to set the scope of a comparison to make costs and benefits calculation. Often it is impossible to rank observed practices in a fair way.

7.3 The study in a larger context

There is no cookbook recipe for carrying out plant modifications and safety assessments at nuclear plants. There are partly conflicting goals which have to be balanced such as for instance plant safety, technical feasibility and cost efficiency. Plant modifications and safety assessments are closely interlinked with other work processes by which plant safety is ensured. It is important to develop systems and structures by which individuals are given opportunity to do their best. Still many things have to be settled on a case by case consideration relying to a large extent on common sense.

A study of this kind can be continued in two ways. It can be repeated in some other area of interest or alternatively, the subject matter can be examined in greater detail. Taking into account the fairly restricted number of people participating in this study, it might be preferable to take a closer look on the safety inspection and involve a larger number of people in the data collection. Such a study could try to validate the good impressions managers have of their people. This would imply a formulation of the findings of the present exercise into a set of a hypothesis to be verified or rejected on the basis of material collected by questionnaires. Such a study may also serve as a first step towards an instrument by which safety culture could be assessed.

An interesting follow up to the study may also be concerned with the interface between the regulator and the power utility. Three different approaches have been identified and the report reflects various aspects of this interface as seen from the power utility. It would be interesting to get information also on how the regulator views this interface.

The study has shown that a benchmark exercise can provide interesting insights through the comparison of practices. The insights can be valuable as such, but even more valuable are the discussions where a better understanding of the reasons behind the practices is sought and alternatives for further improvements are laid out. In such discussions managers should be aware that sometimes there are subtle influences from leadership styles and from the allocation of resources. Thoughtful and wise people are the biggest asset of any organisation, but they should be given enough time to generate these thoughts.

Epilogue

The benchmark was carried out during the second half of 1997 and the report was written during the first half of 1998. This means that the conclusions drawn in the report are based on conditions existing at the plants more than two years ago. This used to be a short time in the nuclear business, but today an increasing rate of change has led to a situation where two years typically will contain many and even large changes. This has also been the case for the three companies participating in the benchmark. Firstly, the benchmark itself has triggered a process of change where many of the recommendations in the report have been brought into plant modification processes. Secondly, there have been changes in the overall structure into which the plant modification processes have to fit. Such changes are for example that Magnox today is the Magnox Generation Business Group, which is owned by BNFL, a large UK based international operator on the nuclear arena. In Sweden the authority SKI has issued new regulation, which has to be reflected in the ways Forsmark is carrying out plant modification and safety inspections. In Finland TVO has been given the responsibility for building and maintaining preparedness to order a new reactor in the case such a project will take off. All these changes have taken place during the normal change in which people leave and new people come. All these changes imply that the situation today is different from what it was two years ago, but the authors of the report are clearly convinced that the development by large has been positive. This conviction does not however change the fact that safety should never be taken for granted, but should always be the object of a continuous attention. Finally, during the two years the two researchers who participated in the benchmark have also collected far more evidence that this kind of study is beneficial. When a benchmark is conducted with an open mind and in an atmosphere of confidence and trust it can provide important findings in developing the work processes that are crucial for maintaining a continued safety at a nuclear power plant.

Acknowledgements

This kind of international benchmark is very rewarding for the researchers involved. To have the favour of speaking in depth with highly competent persons from three well performing companies provides an unprecedented insight into important relationships of management and organisation. In this connection we would like give our sincere thanks to Olle Andersson of FKA for his interest in the results and for his devotedness to get the study done. Finally we would like to thank all the participants in the interviews, without their help the report could not have been written.

A questionnaire on processes of plant modifications and safety assessments

Forsmark Kraftgrupp AB (FKA), Magnox Electric plc (Magnox) and Teollisuuden Voima Oy (TVO) have engaged in a survey and benchmark of their safety inspection practices. The survey will be carried out by VTT Automation and will consist of interviews with people engaged in the plant modification and safety assessment processes. The questionnaire has been written to be used at Magnox and similar questions adapted to their environment have been asked at FKA and TVO. The questions below form the basis of the interviews, but also other questions may emerge in the discussions. Some of the questions are open ended and may require long answers. In these cases the intent is more to stimulate discussions than to give precise answers. It is not expected that all interviewed persons are able to answer all questions, but everyone can concentrate on his own area of expertise. A concrete plant modification project, the replacement of the temperature data processing system (TDP), at Magnox has been chosen to serve as an example for the processes applied in plant modifications and their safety assessments. At FKA and TVO the corresponding example is the installation of a backflushing system of the strainers. Please fill in answers when reading the questions below to give more time for discussions.

1. An organisational background of Magnox

Magnox has been formed in several stages from CEGB and Nuclear Electric. The company is a public limited company and operates six nuclear stations. In addition the company is responsible for decommissioning of three nuclear stations.

1.1 How has this change process been viewed at the Hinkley Point A plant and at the Magnox headquarters in Berkeley?

1.2 How much contact is maintained with former colleagues at Nuclear Electric?

1.3 Many of the processes and the quality control documents have been taken over from earlier processes and documents at Nuclear Electric. Have there been any changes in processes and documents? If so, why have these changes been introduced? How have the changes succeeded?

1.4 Has Magnox placed some overall goals for the modification and safety assessment processes? If so, how is the achievement of these goals monitored?

2. Processes for plant modifications and safety assessments

Plant modifications are defined in the Site Licence Condition 22 for Hinkley Point A. Compliance with this condition is achieved in the Management Control Procedure 21 (MCP21). This also include the requirement to categorise modifications according to their nuclear safety significance. Any category 1 and 2 modification has to go through an Independent Nuclear Safety Assessment (INSA) before it can be implemented. Category 1 modifications have in addition to be endorsed by the Nuclear Safety Committee and get the approval of NII.

2.1 How well do these documents reflect working practice for plant modifications and safety assessments When you are carrying out out your own work, to what extent do you reference to your own work procedures? Is there a separate path for small modifications?

2.2 The MCP21 actually splits into three parts, one for the Technology & Central Engineering Division, one for the power station and one for the Health Safety and Environment Department (HSED). How well do these documents specify the interaction between the three organisations? Are there any contradictions between the documents?

2.3 Specific roles as a Nominated Responsible Engineer, a Case Officer and a INSA Officer are allocated when a modification proposal is initiated. How do these persons interact during the advancement of the plant modification? How are possible disagreement between them handled?

2.4 There is sometimes a benefit if plant modifications can be presented early for the safety assessment. Are such contacts taken between the designers and the safety assessors? Are there any problems connected to such contacts?

2.5 The NII must agree to category 1 modifications before they can be implemented. For major project they may specify hold points. If this is the case who will on behalf of Magnox be involved in this communication? How often will there be person to persons interactions between Magnox and NII?

2.6 It is important that safety issues are considered both broadly and in enough detail. It is also necessary to reflect various technical disciplines. Those involved should have a good understanding of the plant and its basic safety principles. It may sometimes be difficult to find persons with the necessary skills. How is that requirement ensured within Magnox? How is it ensured that the safety assessment is given enough resources and time to do a thorough review? Are the wider system implications of the effects of a specific modification generally considered?

2.7 An important part of the safety assessment is to consider interactions between systems. How is this aspect covered in the plant modification and safety assessment processes? Are there any special precautions to address this issue in the processes?

2.8 What kind of support documents are used to ensure that an overview is maintained over larger plant modifications which may last for several years and involve a large number of parties?

2.9 What kind of arrangements are maintained to ensure that the formal requirements of the plant modification and safety assessment processes are maintained?

3. The replacement of the temperature data processing (TDP) system

The modification of the TDP system has been selected to provide a more concrete understanding of the plant modification and safety assessment processes at Magnox. The questions below are not intended to go into technical details of the TDP system nor the specifics of this modification project. The example is instead intended to be a typical modification project, not too complicated but complicated enough, to illustrate how a modification is initiated, assessed and implemented. The corresponding modification project selected for FKA and TVO is the installation of a backflushing system of the strainers.

3.1 The modification was initially assigned to Category 2 and later changed to Category 1. Was this connected to a change in the proposed new system or to a reappraisal of the nuclear safety importance of the TDP system? How common are such changes in the initially assigned categories?

3.2 The original design of March 1995 was changed in an addendum of June 1995. Which part of Magnox was the originator of this change? How often are changes introduced as a result of the INSA process?

3.3 NII agreed in a letter of 22 December 1995 to the modification. Is it typical that an agreement is reached based on the design material only?

3.4 The modification of the TDP system was entered as a paper of principle and it was decided that the modification should be handled through various stage submission. Who made this decision? Is this a typical procedure? Will the various stage submissions go through the same INSA procedure?

3.5 Did the safety assessment reveal any difficult issues? Have there been any difficulties in implementing the system as planned?

4. The independence and integrity of the safety assessment

The safety review of plant modifications at Magnox can on a very general level be divided into two parts, safety issues being addressed in the proposal for a modification and its corresponding design on one hand and the Independent Nuclear Safety Assessment (INSA) on the other. There is a certain benefit if documentation is produced in a way which makes the INSA easier, but it is also important that the independence and integrity of the assessors are maintained.

4.1 In the assessment process it is important that the assessors have integrity also to come forward with difficult questions. How has it been assured that assessors are aware of their authorities and responsibilities? Has there been any incident where uncomfortable opinions have been suppressed?

4.2 It is important that the assessors are competent and aware of the importance of the assessment. Do Magnox have any special training programmes for their safety assessors? How is the continuous competency development for safety assessors arranged at Magnox ?

4.3 In the assessment of plant modifications economic considerations may also emerge in parallel with the safety. Are the safety assessors typically aware of the costs involved? To what extent are cost considerations allowed to interfere with the safety assessment process?

4.4 The assessors are sometimes forced to work under time pressure. How often is that occurring? When an urgent assessment task is emerging how is then the assessment effort reallocated among available persons?

4.5 How is the assessor selected for a specific modification? Various assessors may have differnt styles in performing their assessment. Is that influencing the assessment made? Are there any mechanism or interaction which may compromise the independence of INSA?

4.6 It is important that the assessors get all relevant material for their assessment. Are all supporting documents submitted automatically or does INSA have to request them? How is the completeness and quality of the documents used in the assessment process ensured? Do the authors of safety cases make their safety concern explicit or is there a tendency to hide them from the INSA?

5. Assessment of the assessment process

Assessments are typically targeted at documents produced by various processes. One aim of the asessment is to ensure that the safety case is complete and no important safety issues have been missed. It is however necessary to assess not only technical but also administrative systems. At the same time also the assessment process itself should go through regular assessments to make it more efficient and to utilise experience obtained.

5.1 Assessments should be targeted not only to the documents generated by various processes, but also to the processes themselves. Are the safety assessment processes a target of assessments or audits? Are these assessments systematised? How often are they carried out?

5.2 It is also necessary to assess the efficiency of the assessment processes. The results of such assessments should be used to further develop the assessment processes themselves. Is there a systematic collection of experience from the assessments to further improve the assessment processes?

5.3 It is important to give the personnel engaged in the assessments challenges and exposure to forward thinking within the nuclear safety area. How has this aspect been considered within Magnox? Have there been any systematic contacts to international co-operation and research to achieve this?

6. Some final questions

Thank you for your patience in going through the questions so far. The following more philosophical questions end this questionnaire.

6.1 Sometimes a disagreement on the importance of a specific issue may emerge between designers and safety assessors. How are they resolved? Would it be beneficial to aim at a consensus in the decision processes concerning safety and its assessment? How can such a consensus reached? How often does disagreements occur?

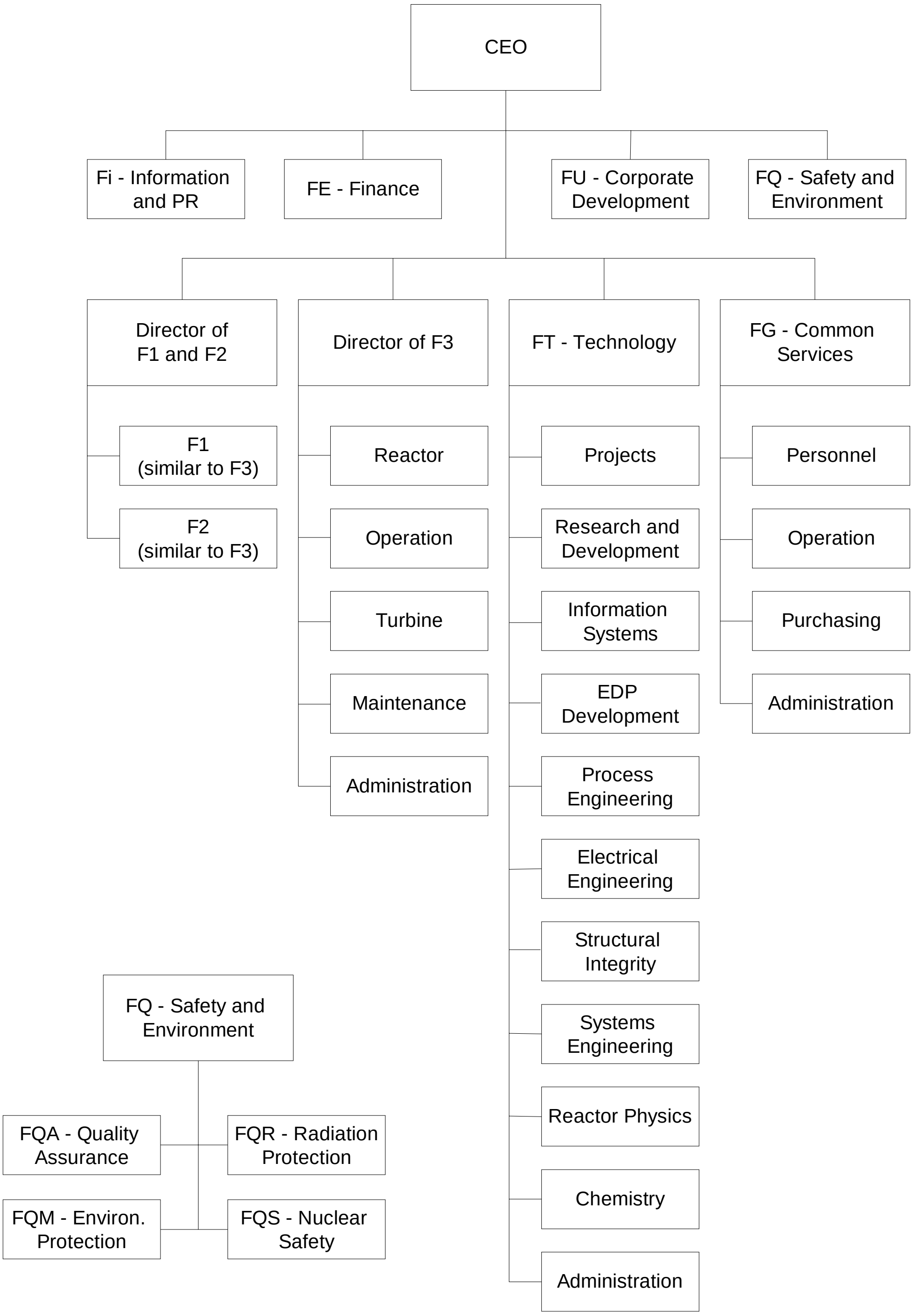
6.2 It is important that the assessed and the assessors place confidence and trust in each other. How would you characterise the situation at Magnox? Is it easy to convince designers that the assessment is an important part of the plant modification processes?

6.3 How can the assessment be made as efficient as possible? How can the design procedures be developed to create documents which are easy to assess?

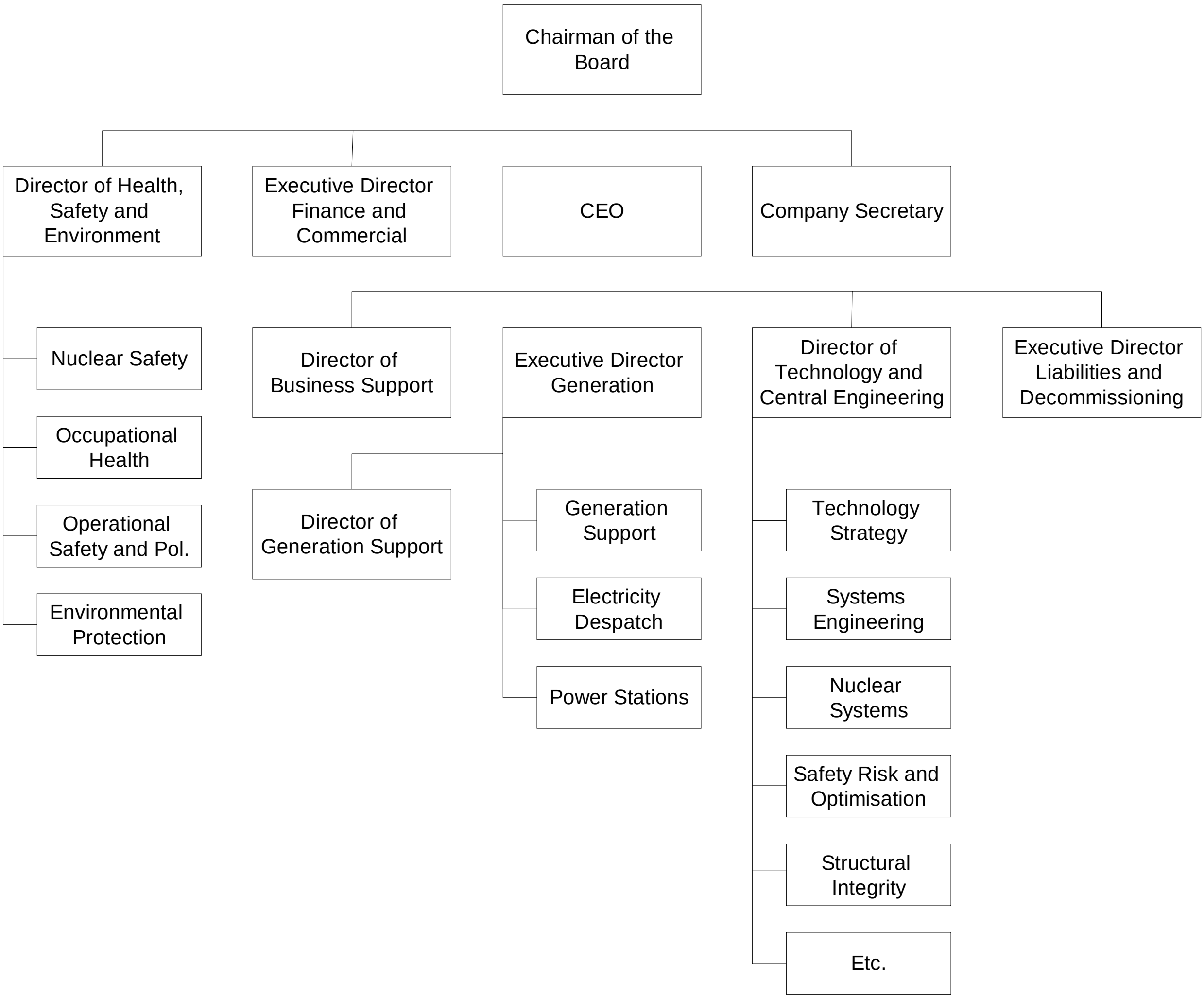
6.4 What are the most commonly found problems in the plant modification process? How could these problems be alleviated? How could the assessment process be further improved?

Organisational charts

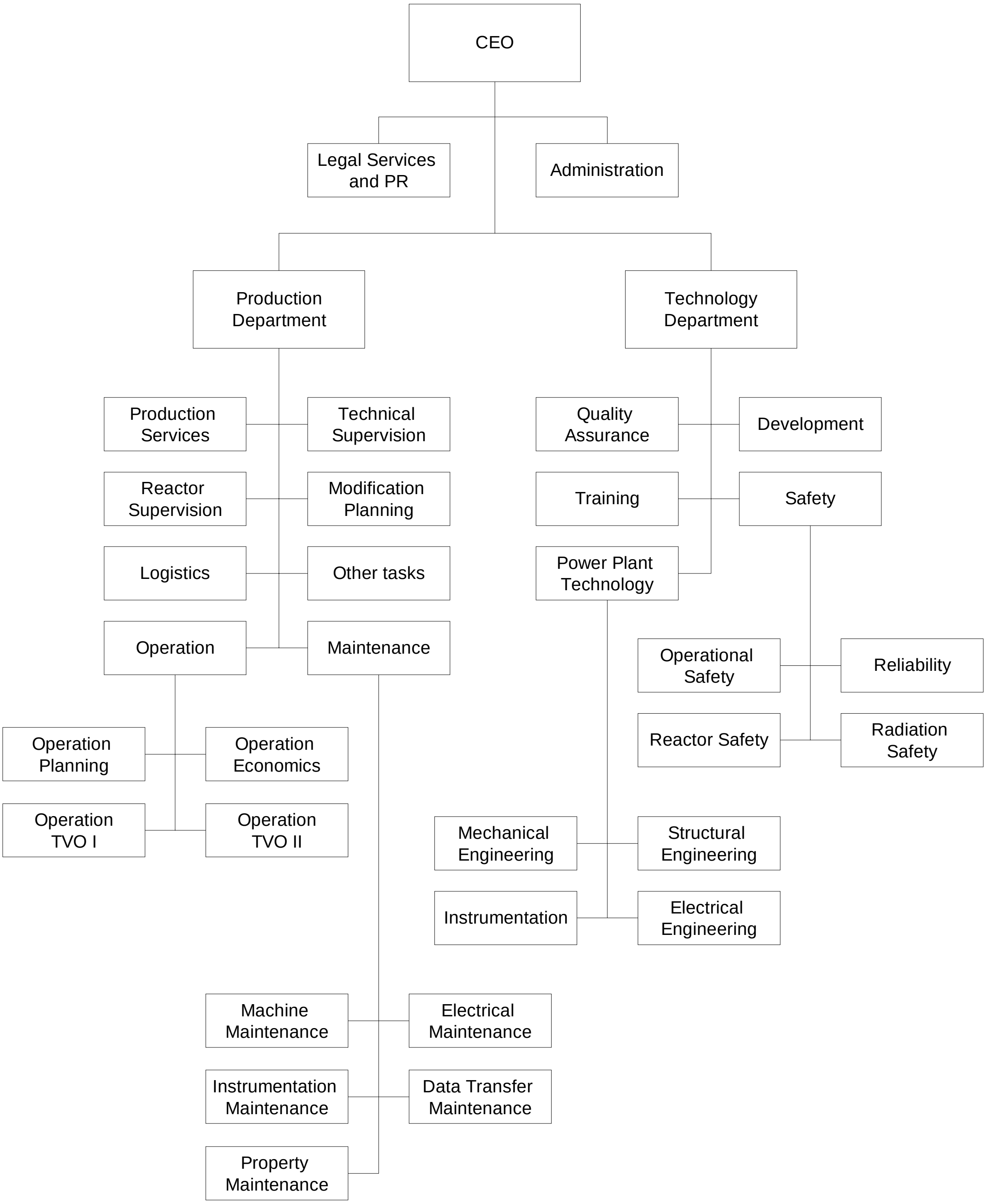
Forsmarks Kraftgrupp AB organisation chart



Magnox Electric plc organisation chart

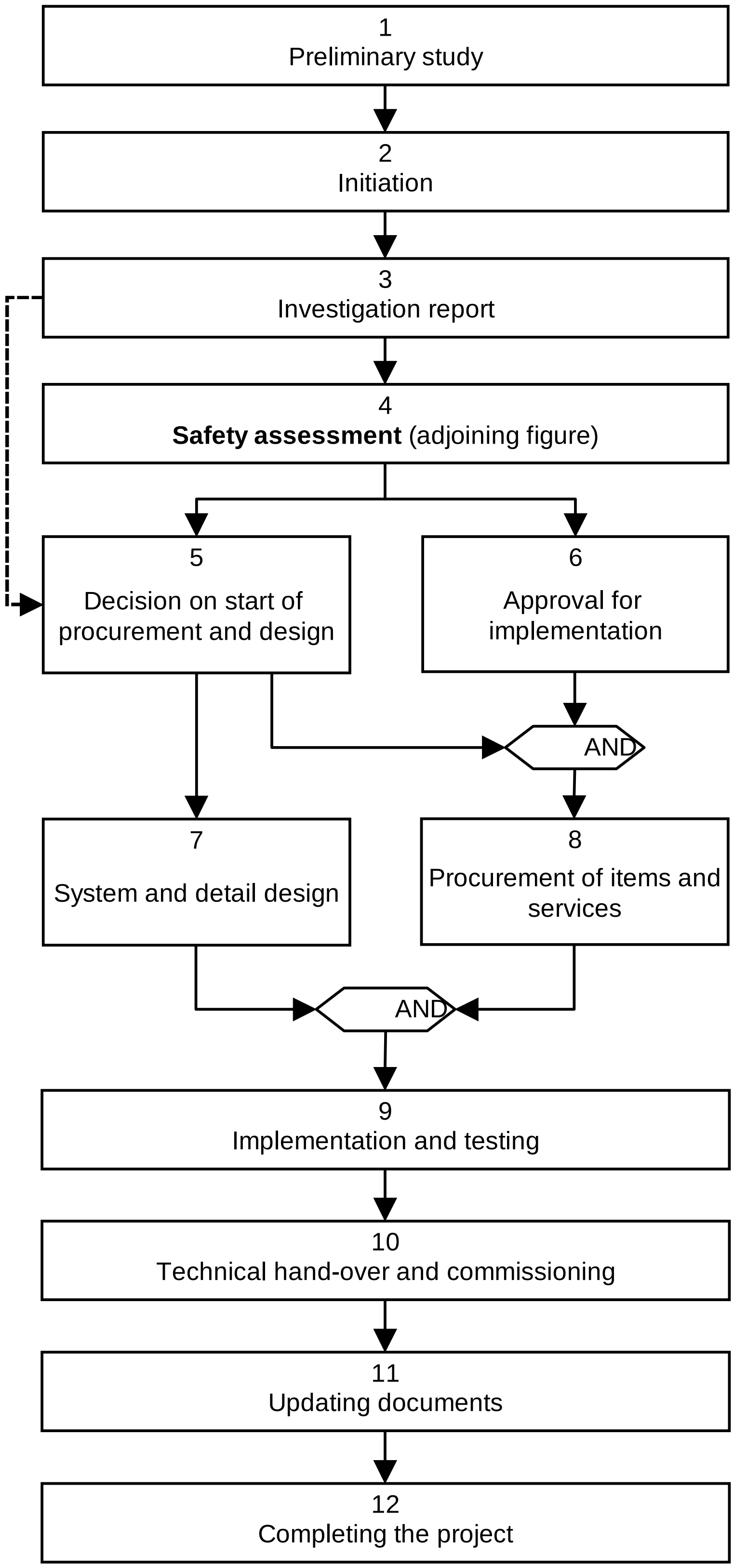


Teollisuuden Voima Oy organisation chart

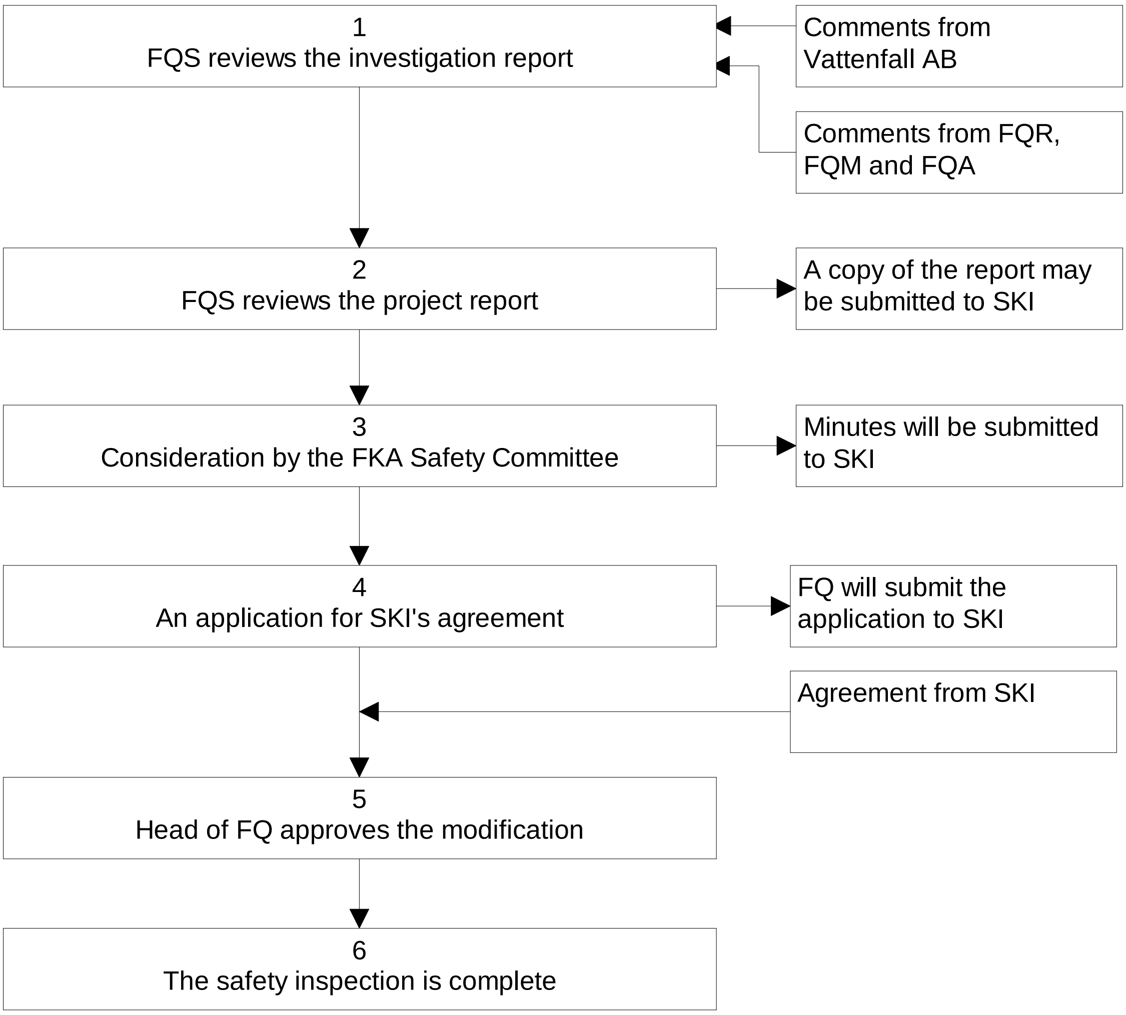


Modification processes

FKA's plant modification process for category 1 proposals



FKA's safety assessment procedure for category 1 proposals



Magnox Electric's plant modification process for category 1 and 2 proposals

1
Initiation

↓

2
Preparation of a Plant Modification Proposal (PMP)

↓

3
Verification of submission

↓

4
Safety assessment (adjoining figure)

↓

5
Construction and procurement

↓

6
Implementation and testing

↓

7
Commissioning

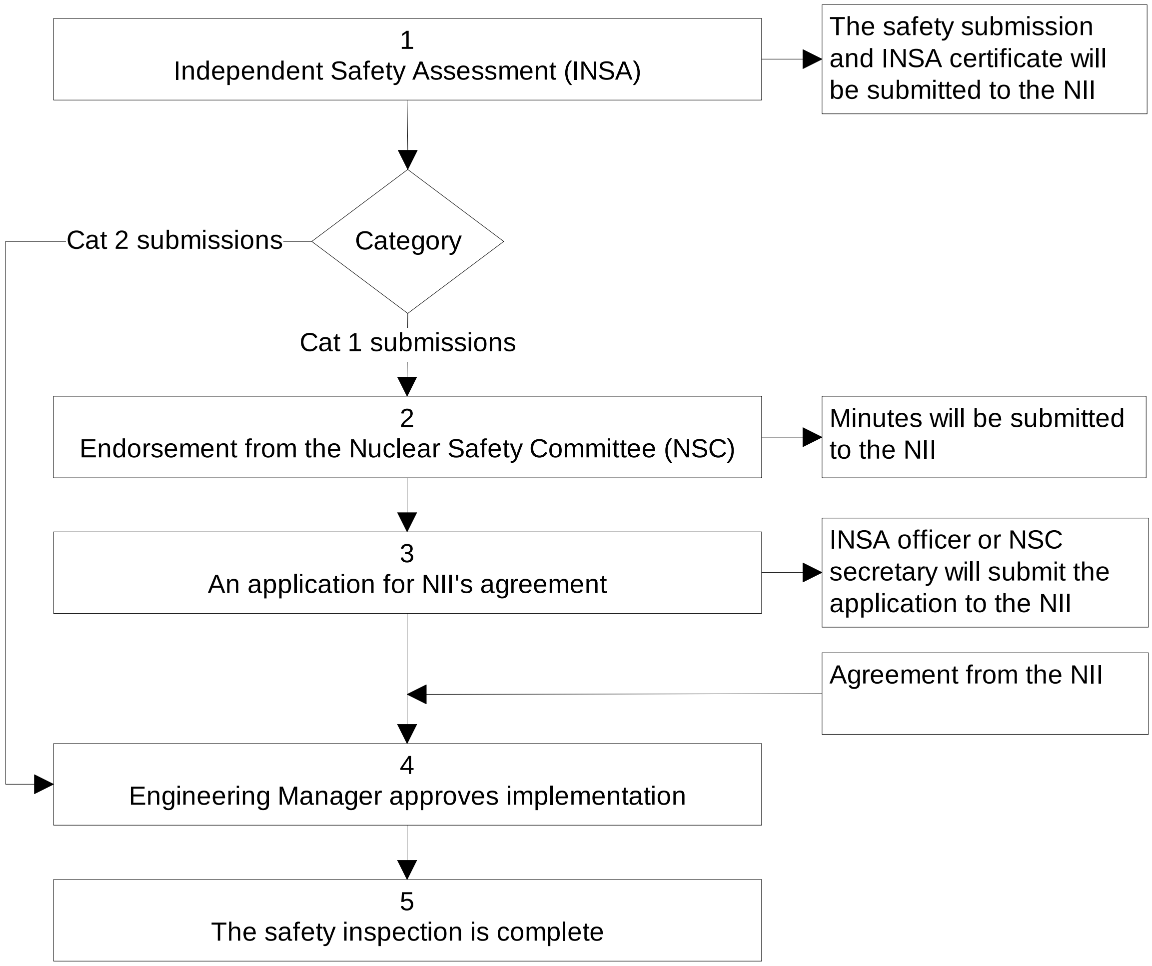
↓

8
Updating documents

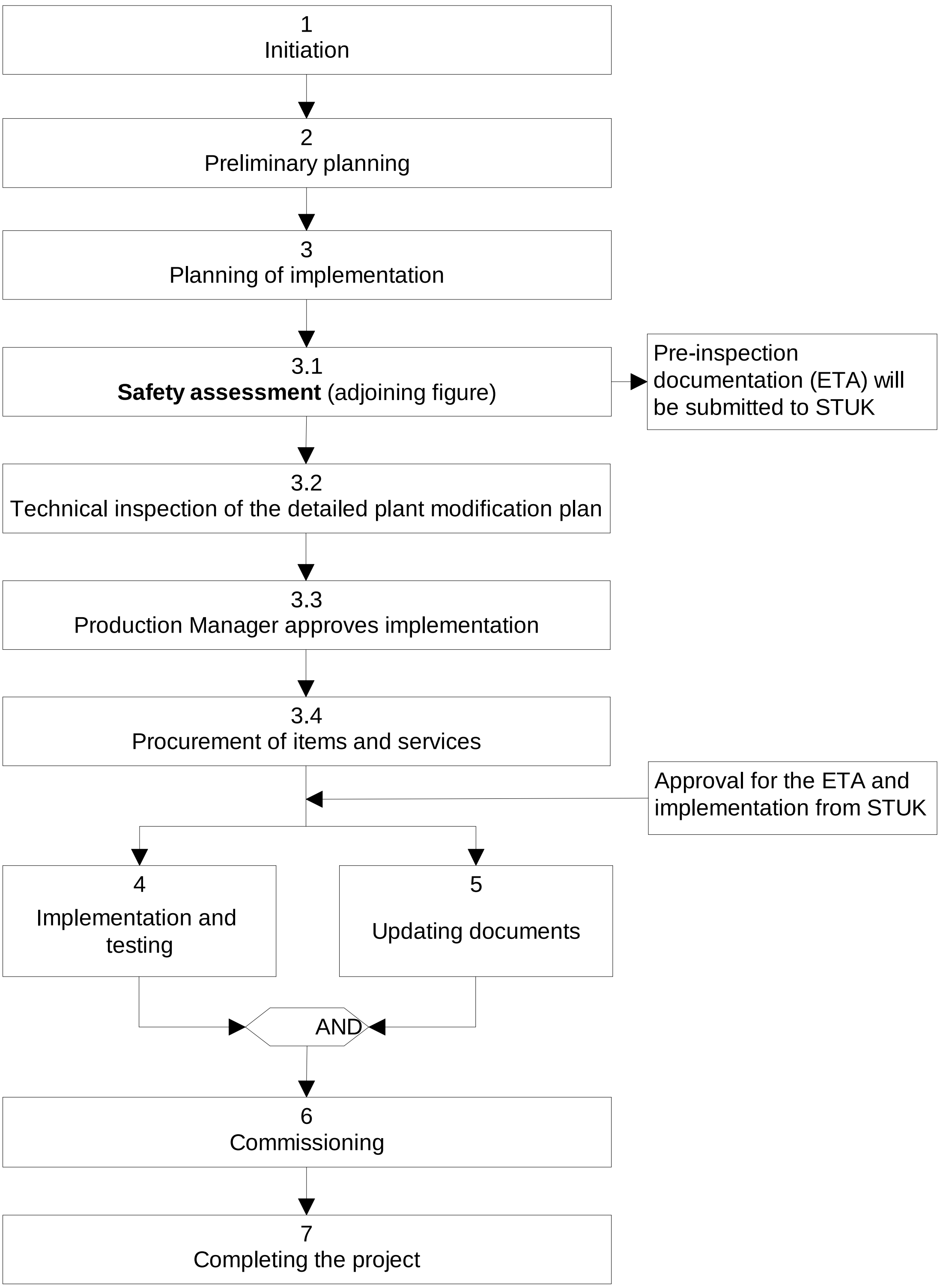
↓

9
Completing the project

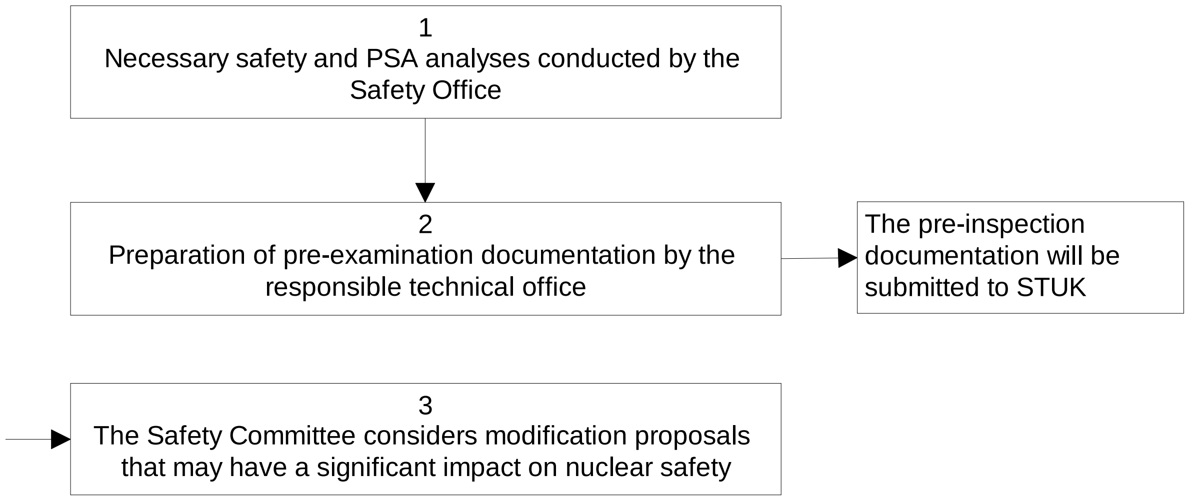
Magnox Electric's safety assessment procedure for category 1 and 2 proposals



TVO's plant modification process (regular route)
for category 1, 2 and 3 proposals

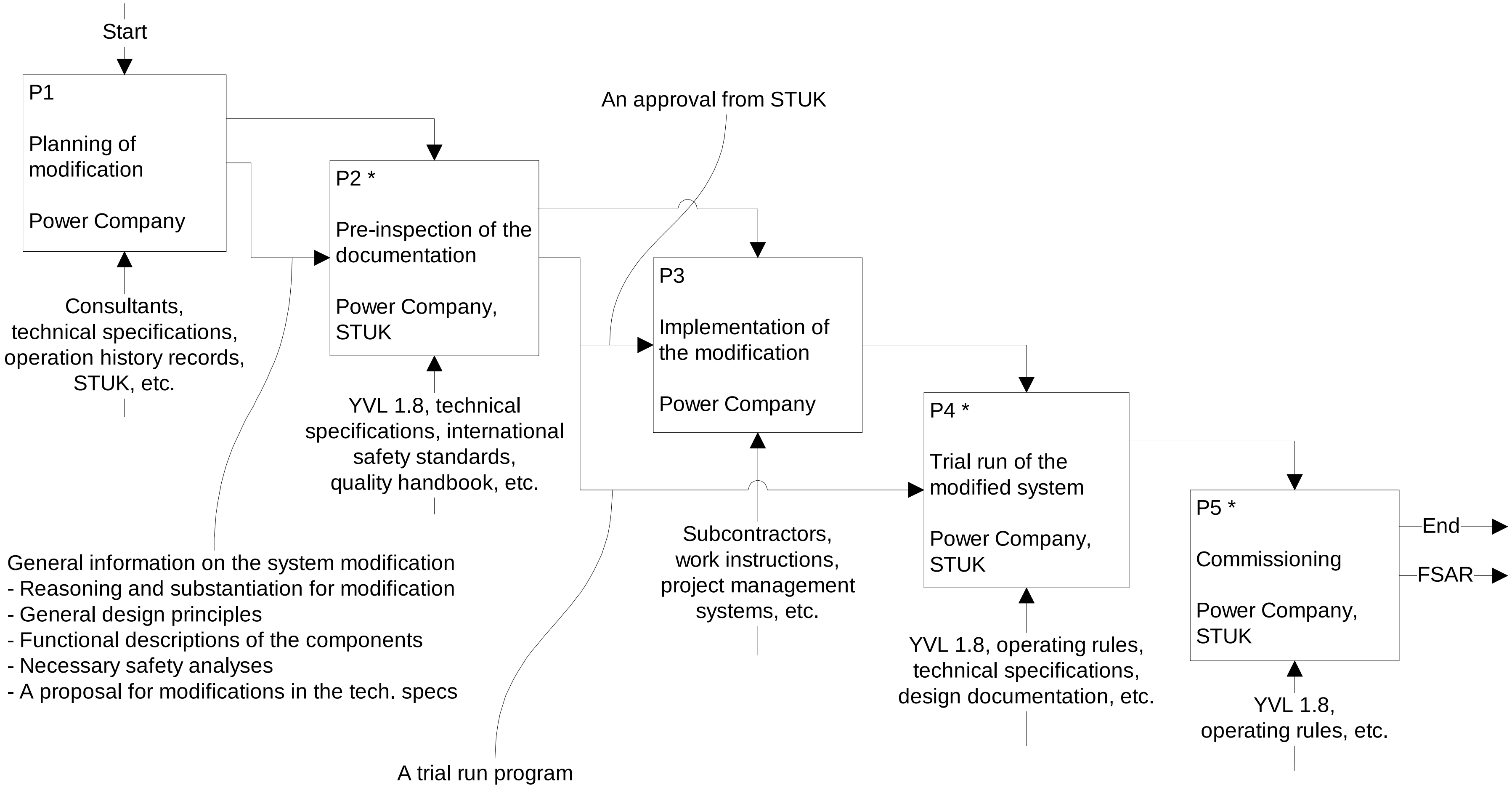


TVO's safety assessment procedure (regular route) for category 1, 2 and 3 proposals

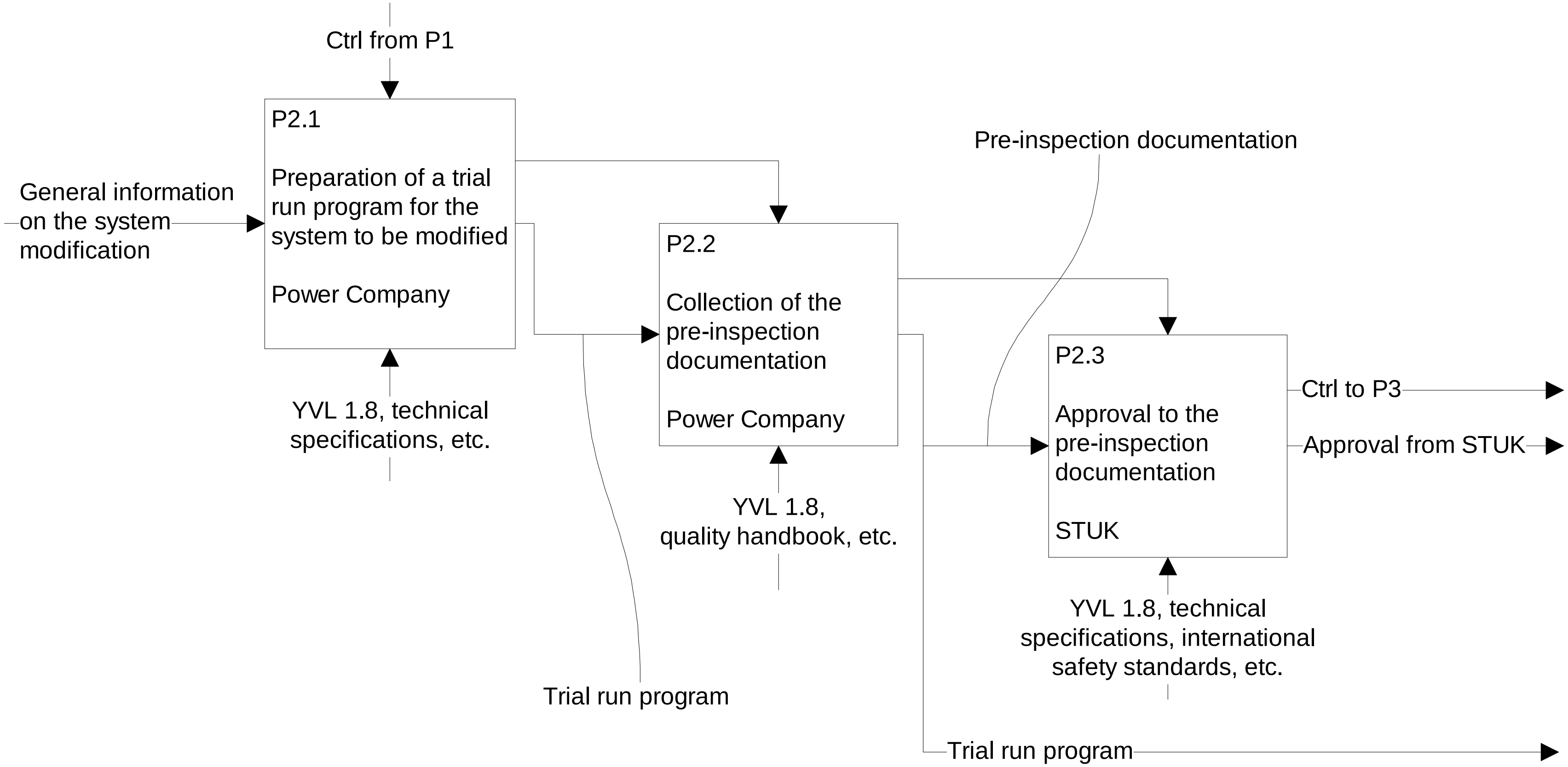


APPENDIX 4

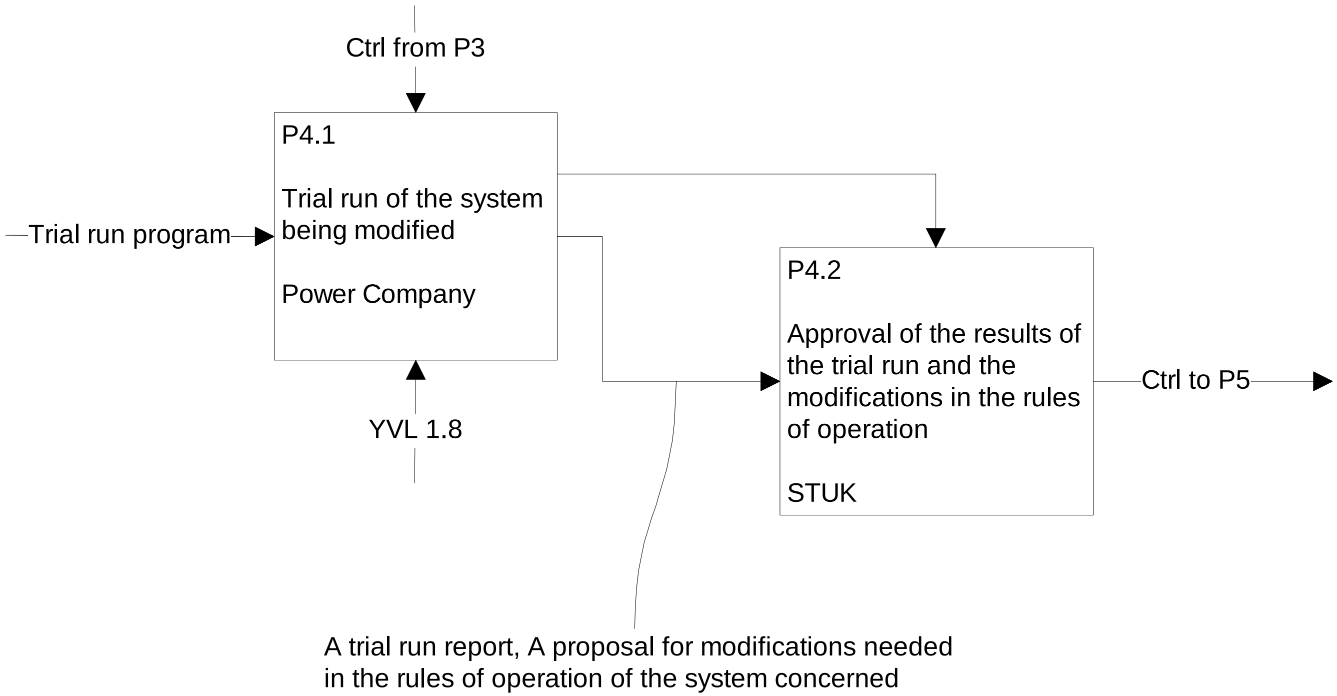
A general system modification process model for Finnish nuclear power plants, Requirements issued by the Finnish Radiation and Nuclear Safety Authority (STUK) in YVL 1.8 - Overview



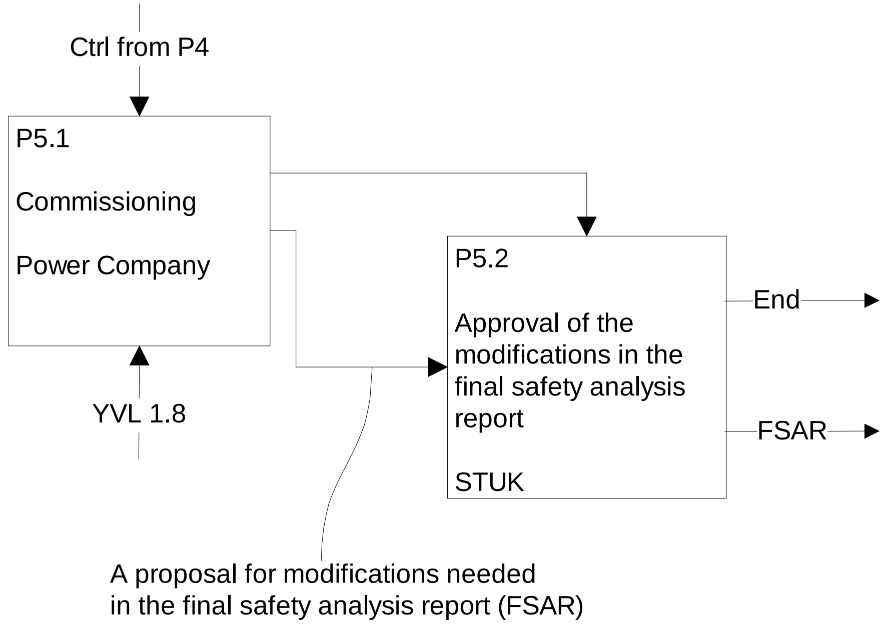
P2 Pre-inspection of the system



P4 Trial run of the system



P5 Commissioning of the system



Published by

Vuorimiehentie 5, P.O.Box 2000, FIN-02044 VTT, Finland
Phone internat. +358 9 4561
Fax +358 9 456 4374

Series title, number and report code of publication

VTT Research Notes 2015
VTT–TIED–2015

Author(s)
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Title
An international benchmark on safety review practices at nuclear power plants

Abstract
A benchmarking exercise on safety review practices at nuclear power plants in Finland, Sweden and the United Kingdom has been carried out. In the exercise a comparison was made between documented practices at the Forsmark, Hinkley Point A and Olkiluoto nuclear power plants. In addition a total of 28 persons at FKA, Magnox and TVO were interviewed on their views on the efficiency of the plant modification processes in the later half of 1997. One specific example of a plant modification was selected from each of the nuclear power plant sites to provide a basis for the comparison. The report gives an account of the methodology used, a description of the plant modification projects, impressions from the interviews, potential problem areas and suggestions for possible improvements.

Keywords
nuclear power plants, benchmarking, plant modification, safety assessments, safety practices

Activity unit
VTT Automation, Industrial Automation, Tekniikantie 12, P.O.Box 1301, FIN–02044 VTT, Finland

ISBN
951–38–5638–0 (soft back ed.)
951–38–5642–9 (URL:http://www.inf.vtt.fi/pdf)

Project number

Date
February 2000

Language
English

Pages
54 p. + app. 19 p.

Price
B

Name of project

Commissioned by
Forsmark Kraftgrupp AB (FKA); Magnox Electric plc, Berkeley Centre; Teollisuuden Voima Oy (TVO)

Series title and ISSN
VTT Tiedotteita – Meddelanden – Research Notes
1235–0605

Sold by
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