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Commissioning of Nuclear Power Plants: Training and Human Resource Considerations

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COMMISSIONING OF NUCLEAR POWER PLANTS: TRAINING AND HUMAN RESOURCE CONSIDERATIONS

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NUCLEAR ENERGY SERIES

Commissioning of Nuclear Power Plants: Training and Human Resource Considerations

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FOREWORD

This publication is primarily intended for use by nuclear power plant (NPP) operating organizations and project organizations that are responsible for the construction and commissioning of NPP projects. However, it should also be of value to design and technical support organizations, research institutes, and regulatory bodies. It is expected that Member State organizations will use this information to improve their training programmes and other aspects of human resource management for commissioning of NPPs.

This publication was developed through one of the activities under a Project in the IAEA's 2006-7 Programme entitled, Achieving Excellence in the Performance of Nuclear Power Plant Personnel. The principal objectives of this project are:

- To enhance the capability of Member States to utilize proven practices accumulated, developed and transferred by the Agency for improving personnel performance and maintaining high standards, and
- To demonstrate how positive attitudes and professionalism, appropriate performance management, adherence to a systematic approach to training, quality management and the use of effective information and knowledge management technologies contribute to the success in achieving organization objectives in a challenging business environment.

The IAEA wishes to thank the participants and their Member States who contributed examples for this report and for their valuable review and critique of this publication. Additional thanks to the organizations in the Member States that participated in the survey regarding training and human resource experiences for commissioning of NPPs. The information provided in this survey was an invaluable input to this publication.

The IAEA officer responsible for this publication was T. Mazour of the Division of Nuclear Power.

CONTENTS

1. INTRODUCTION

The purpose of this publication is to disseminate lessons learned information regarding training and human resource considerations for commissioning of nuclear power plants (NPPs).

1.1. Background

The IAEA Technical Working Group on Training and Qualification of Nuclear Power Plant Personnel (TWG-T&Q) recommended that the Agency develop a publication on experiences gained regarding commissioning training for nuclear power plant projects This recommendation was made in recognition that in many of the Member States with operating nuclear power plants it has been some years since an NPP has been commissioned, and most of the staff with experience in commissioning have since retired. Additionally, in a number of Member States serious consideration is being given to initiating new nuclear power programmes. This publication is intended to provide useful information for both of these situations.

1.2. Scope

This publication is intended to apply to commissioning of NPP projects in Member States that are initiating their nuclear power programmes, as well as in those Member States with established nuclear power programmes.

This publication addresses training and human resource issues for:

— The personnel that will operate and maintain the plant, both during the commissioning phase and also once it is in service (all positions in the operating organization)
— All personnel in the commissioning organization (e.g., startup/test engineers, test development engineers, planners, quality management, personnel, and managers/supervisors of these staff, who collectively, are responsible to ensure that the plant has been properly designed and constructed and is ready for safe and reliable operation)

While other personnel may also benefit from and participate in this training, such as regulatory body personnel, vendors and suppliers, the training and human resource considerations for these personnel are not specifically addressed in this publication. This publication also does not specifically address the training and human resource considerations for construction/erection personnel, such as welders, carpenters, pipe fitters, electricians, and other technicians.

In addition to information that has general applicability, training and human resource considerations for the following situations are specifically addressed in this publication:

(1) The first NPP in a country or an organization
(2) The first of a kind (FOAK) NPP for an existing NPP fleet
(3) Rapid expansion of an existing NPP fleet

1.3. Users

This publication is primarily intended for use by NPP operating organizations and commissioning organizations that are together responsible for planning and conducting commissioning tests, as well as the training organizations established to support these organizations. This publication is intended for use by managers in these organizations, as well as training specialists. However, it should also be of value to design and technical support organizations, research institutes, and regulatory bodies.

1.4. How to use this publication

This publication is intended to be used as a tool to assist those who are faced with responsibilities to acquire and develop the human resources needed to support commissioning of an NPP project. Such users will find, in Section 2 of the publication, training and human resources information that applies to all NPP projects, in areas such as:

— Staffing plans for commissioning
— Commissioning training plan development and implementation
— Content of and methods for training for commissioning
— Training materials for commissioning
— Control room simulator training to support commissioning
— The organization of training for commissioning

Additionally, separate sections are provided to specifically address these situations:

(1) The first NPP in a country or an organization (Section 3.1).
(2) The first of a kind (FOAK) NPP for an existing NPP fleet (Section 3.2).
(3) Rapid expansion of an existing NPP fleet (Section 3.3).

To supplement this information, appendices are included at the end of the publication providing more detailed information regarding training and human resource considerations for selected NPP commissioning projects.

2. OVERALL TRAINING AND HUMAN RESOURCE ISSUES FOR COMMISSIONING

2.1. Terminology and background

Before a nuclear power plant is put into commercial operation, the functional adequacy of the installed components and systems, as well as the competencies of operating organization personnel must be tested to demonstrate that the plant can be operated safely and reliably. The main objective of commissioning is to confirm that the design intent of the components, systems and the plant as a whole are achieved. Commissioning objectives also include optimisation of the plant system functions, verification of the operating procedures, getting operating personnel familiar with plant systems, and producing the plant initial startup and operating historical records.

The principal activities performed during commissioning are of three types:

— Those associated with the final construction and installation of plant equipment;
— Those specific to the planning for and conduct of commissioning tests; and

— Those associated with operation of the plant (either to support commissioning tests, or to operate and maintain equipment that has been turned over to the operating organization).

Thus, personnel performing the above activities generally are members of one of the following organizational units:

— construction
— commissioning
— operations

There are a variety of ways in which the construction, commissioning and operations units are organized, depending upon factors such as the industrial practice and experience regarding nuclear power in the country, contractual arrangements, and the design of the plant. Irrespective of the organizational approach selected, the commissioning should be planned and implemented in such a manner that operating organization personnel get acquainted with operation of the plant during commissioning and, at the same time, it can be verified that the training and qualification of operating personnel are sufficient. To achieve this objective, the operating organizations should be responsible to ensure that:

— persons who have the necessary expertise and experience prepare, assess and approve operating instructions and test programmes, as well as documentation of test results;
— a sufficient number of people who have been trained, qualified and authorized for their jobs are available for commissioning operations;
— an appropriate organization for implementing the test programme has been set up;
— future plant operators are involved in the preparation, performance and analysis of the tests and of the lessons to be drawn for future plant operation.

The phases of NPP construction, commissioning and operation overlap. This means that at the same time some systems are under construction, other systems are being commissioned and still others are already being operated. However, for individual systems, exact borders between construction, commissioning and operation need to be defined. This situation is illustrated in Figure 1.

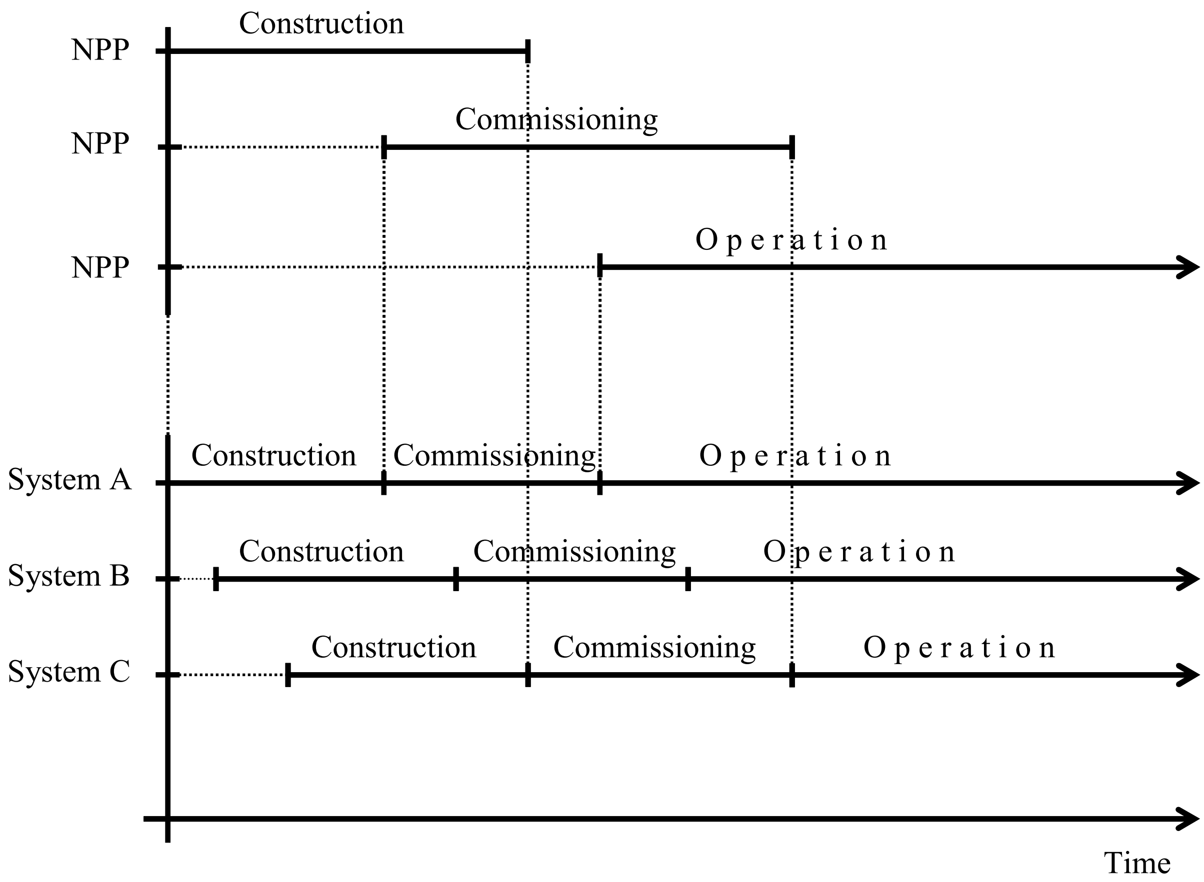


Figure 1. Overlap of Construction, Commissioning and Operations Phases.

The test programme for a nuclear power project is defined during the design stage, with detailed test procedures developed and approved some months prior to their use. The test programme covers all required tests, including equipment tests before installation, tests of installed components and systems, and overall plant tests. The test programme is jointly implemented by the commissioning and operating organizations. Top level management needs to promulgate a clear policy that assigns responsibilities for planning and implementation of the test programme during the commissioning stage.

The commissioning organization is usually a composite team, made up of personnel from the engineering, procurement and construction (EPC) contractor, equipment supplier, construction manager, and plant owner (depending on the structure of the project). Upon completion of commissioning tasks, these people will generally return to their original organizations.

Operation of individual plant systems and the entire plant during commissioning should be performed by suitably trained and qualified operating personnel, provided by the operating organization and integrated into the commissioning programme. The following services are also necessary to be provided by the operating organization to the commissioning organization:

— Maintenance, including personnel and facilities.
— Support services such as water chemistry and radiological protection.
— Engineering support to assess commissioning test results and resolve non-conformances.

The commissioning programme is divided into phases to ensure the completion of all commissioning tests in a logical, safe and effective sequence. The following is an example of such phases for a typical PWR:

Pre-Operational Tests

This phase covers all tests of individual equipment, components and systems (including what are sometimes defined as "construction tests" such as those that ensure proper pump rotation, and motor operation). These tests are performance-based, mainly for demonstration of the achievement of the proper functions described in design documents. Commissioning tests of the electrical supply system are performed during this phase, either prior to or in parallel with other system tests.

Hot Functional Tests I (without Fuel Loading)

During this phase, the reactor coolant system is operated for the first time together with auxiliary systems. During this phase, the reactor coolant system reaches normal operating pressure and temperature by running the reactor coolant pumps. Plant operation is demonstrated to the extent possible without nuclear steam generation. The satisfactory completion of these tests is a prerequisite for initial core loading.

Hot Functional Tests II

This phase begins with initial core loading. During this phase the reactor is kept sub critical. The hot functional tests continue with the reactor core and complete core instrumentation to demonstrate the operability and safety of the entire nuclear power plant before the start of nuclear operation.

Plant Overall Nuclear Tests

These tests start with initial criticality and then include a step by step approach covering all commissioning tests up to full power testing of the reactor. Within the 0–30 % power range, steam is first discharged through the bypass system into the turbine condenser. After the required steam quality is achieved, the turbine generator is then synchronized and electrical power is fed to the grid. When full power is reached, a number of tests are performed to demonstrate safe and reliable operation of the plant before it is turned over to the operating organization.

Figure 2 shows "typical" staffing for the construction, commissioning and operating organizations during an NPP project.

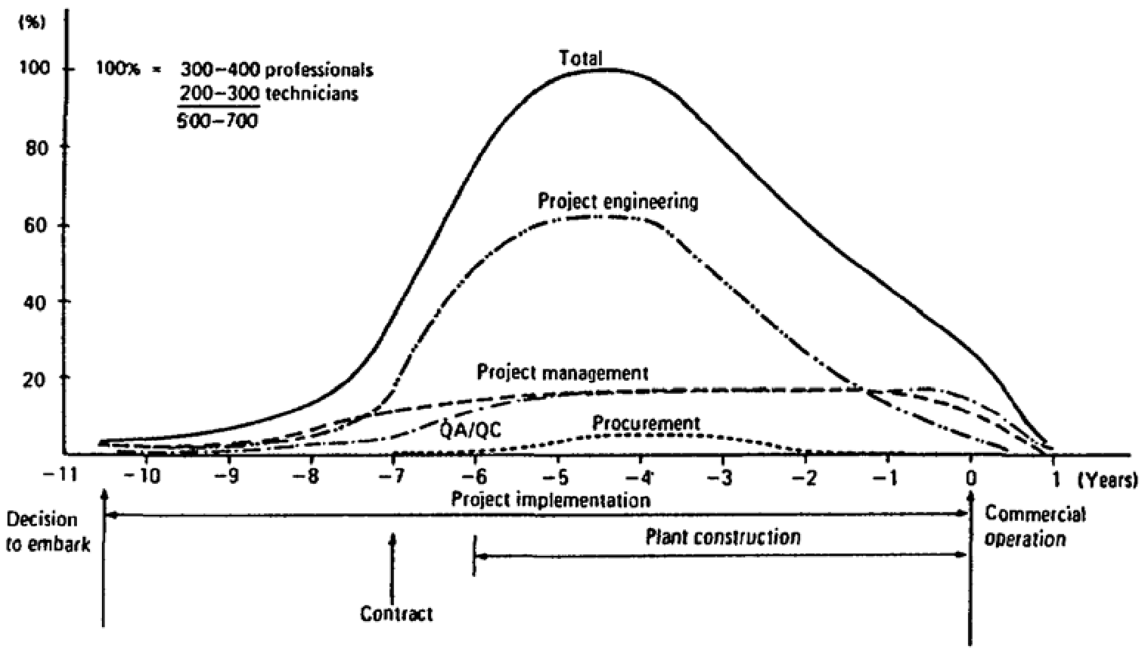


Figure 2. Typical NPP project staffing.

Working arrangements for commissioning should, as far as practicable, make use of operating personnel so that they become familiar with the plant during commissioning, and gain the unique knowledge and experience available during this period.

2.2. Types of NPP projects and their structures

The three most common types of contracts used for NPP projects are (1) turnkey, (2) split package contracts, and (3) projects managed by the plant owner/operator. For a turnkey project, the owner has one contract with the main supplier. The main supplier has overall responsibility for construction, and turns over responsibility for the project to the owner/operator in stages during the commissioning phase. For a split package project the owner has multiple contracts with suppliers; often with the split being between the nuclear island and the balance of plant. For a project managed by the owner/operator, contracts are awarded to various suppliers with the owner/operator maintaining project management responsibility throughout the project. The tasks to be performed for an NPP project are the same irrespective of the contract type; what changes among the three contract types is how the responsibilities are distributed among the organizations involved.

The type of project for NPP construction has a significant effect on the responsibilities and organization of training for commissioning. For a turnkey contract, the organization responsible for the turnkey project generally has the lead responsibility for developing and conducting this training. For a split package contract, or a project managed by the plant owner/operator, it is more likely the case that the project organization/operating organization will have the lead role. The type of contract selected is generally related to the previous experience of the owner/operator with NPP commissioning and operation. An operating organization that already has other NPP units in operation, particularly those of a design similar to the new NPP project, is more capable of organizing and conducting training for commissioning. In any case, detailed technical information from the supplier organization(s) will be an important input for these training programmes.

2.3. Considerations regarding training and HRM issues for turnkey and split-package contracts

The following are examples of training and human resource management considerations that are particularly important for turnkey or split-package NPP projects:

— Training materials and programmes are formatted and structured in such a way that they can be updated and maintained by the operating organization, and that they are compatible with existing and/or planned training and human resource management systems of the organization.
— Responsibilities for providing and managing training during construction and commissioning are clearly defined. Some organizations have chosen this time as an opportunity to establish a specialized training organization, either as a part of the NPP operating organization, or as a separate organization, owned and operated by a technical support organization (TSO).
— Terminology and nomenclatures for systems, components, and operations used for training need to be the same as used in NPP technical documentation.
— Training opportunities during commissioning need to be defined for future operators; such as training in the equipment suppliers' country of origin and practical training in the plant
— Identification of how the Systematic Approach to Training (SAT) will be implemented and by whom.
— Responsibilities and schedule for providing a full-scope control room simulator for the plant, and delivery of simulator training (see Section 2.6 for additional information in this regard).
— Supplier responsibility to develop the competencies of future plant operators, including ensuring that the supplier, owner, and commissioning personnel all have the same standards for safety and quality. (in some cases, for the first NPP project in a country, the supplier has retained responsibility for operating the plant for the first year or more of operation).

2.4. Staffing plans for the commissioning phase

The parts of the project plan that are most important for training for commissioning are the project staffing plans (for both commissioning and operating organizations). NPP operating organizations indicated that their staffing plans for commissioning were initiated shortly after a decision was made to go forward with an NPP project, and were finalized from 6 to 24 months prior to the start of component testing[1]. In most cases, the operating organization has the lead responsibility for preparing this plan. However, in some cases the project organization is responsible, or the plan is jointly prepared by the operating and commissioning organizations. This plan should include a schedule showing how the initial recruitment and selection of plant personnel will be implemented, as well as an analysis of the required number of people in each of the functional areas (job positions) needed for commissioning and the levels of experience/expertise needed for each function/position. The staffing plan should have, as a top level objective, to include sufficient time for project personnel to complete the training needed to develop the competencies needed for their

[1] Activities related to the preparation of this publication included a survey that was distributed to organizations that had recently commissioned NPPs, or that were in the process of constructing NPPs. This and other information regarding characteristics of commissioning training and HRM were derived from the responses to this survey.

positions. As indicated in Paragraph 4.47 of *Commissioning for Nuclear Power Plants,* IAEA Safety, Guide, NS-G-2.9;

> "Personnel engaged in commissioning activities should be suitably qualified and experienced for the level of responsibility and importance to safety of their work. The necessary level of qualification and experience should be specified for each position in the organization. In addition, provision should be made for training personnel who participate in the commissioning process in certain aspects of the plant site and methods of working."

Many NPP operating organizations have found it useful to establish targets for the ratio of experienced/inexperienced personnel for commissioning in each position/function. These targets are generally in the range of at least one-third of the total number of personnel recruited for the NPP operating organization to have previous NPP operating experience. Other NPP operating organizations have established a target of having experienced persons in all key positions for commissioning (20 to 30 key positions identified). Certainly, the availability of experienced personnel will be strongly influenced by the extent to which the operating organization has previous experience, and the growth rate of the nuclear programme (it is important to balance the need for having experienced personnel for commissioning, with the need to maintain sufficient experienced personnel to safely and effectively operate and maintain existing units). For turnkey or split package NPP projects, some or all of the experienced personnel may be provided by the main supplier. However, in this case the staffing plans need to include provisions for turnover of responsibilities for plant operations from the supplier to the owner/operator organization.

2.5. Training programmes and plans

Training programmes for commissioning are initially developed from 12 to 78 months before fuel loading, and continually revised. In many cases the commissioning and operating organizations have separate training programmes (particularly for turnkey projects). However, personnel from both organizations often participate in common training activities. For some topics, specialists from the commissioning organization are the most suitable persons to lead these training activities (with suitable support from training specialists to ensure that training materials are appropriately prepared).

Many organization's training programmes require individual training plans for each person assigned to the commissioning phase. In other cases these plans are developed on a job position basis, rather than for each individual.

As indicated in IAEA Safety Standards Series No. NS-G-2.8, *Recruitment, Qualification and Training of Personnel for Nuclear Power Plants,* and IAEA Technical Reports Series No. 380*, Nuclear Power Plant Personnel Training and its Evaluation A Guidebook*, it is considered a good practice to use the Systematic Approach to Training (SAT) as the basis for all training for NPP operating organization personnel. Using SAT from the very beginning of an NPP project for these personnel provides an opportunity to maximize the contribution of SAT to effective and efficient training. The following topics/activities are typically included in an SAT-based commissioning training plan, consistent with individual job responsibilities:

— Objectives, main aspects, stages and sub-stages of the commissioning programme and major hold points
— Methods of and techniques for commissioning

- Roles and responsibilities for commissioning
- Conduct of testing while maintaining the plant in a safe condition
- Procedure changes and design changes
- Permanent and temporary modifications
- Work control and equipment isolation
- Interfaces of construction, design and operation organizations with commissioning activities
- Test limitation boundaries in mechanical and electrical systems
- The criteria for and importance of reporting incidents
- Safety culture (taught as an integrated part of work processes)
- Quality assurance programme for NPP commissioning
- Required form and content of working procedures
- Methods for review and approval of tests results, including assessment of acceptability of test results
- Nuclear safety, industrial safety, fire protection and radiation protection requirements
- Design criteria, and operational limits and conditions for the plant
- Environmental protection and management including waste management
- Coping with anticipated emergencies at the plant being commissioned
- Fuel handling duties and responsibilities including emergencies
- Project management tools including project scheduling software
- Practical training on plant systems (system walk downs, operating equipment during component/system testing)
- Practical training during commissioning of a similar NPP
- Reading plant drawings and system/component nomenclature
- Authorization process for personnel prior to job assignment (or task assignment)
- Authorization schedule for personnel relative to fuel loading

Completion of any NPP basic training included in training plans should be considered as a prerequisite for beginning job-specific commissioning training**.** Completion of required commissioning training should be an obligatory qualification requirement for commissioning personnel, as should the required level of education and experience.

The duration of commissioning training programmes for key positions is typically from 12 to 36 months (with a median of 18 months). For other positions, such as for technical support organization (TSO) and maintenance personnel, the duration is less.

In some Member States, the commissioning training plan is required to be approved by the nuclear safety regulatory body, while in others not.

2.6. Training materials for commissioning

Most of the training materials developed for the commissioning phase are also suitable for use by the operating organization once the plant is operational. Therefore re-use of material is important, including ensuring that the use of terminology and nomenclature for systems, components, and operations used in training materials is the same as that used in NPP technical documentation.

For projects where the owner/operator is the manager, the organizational unit responsible for training material is generally the training unit within the operating organization. When the project is a turnkey, the training organization is sometimes a part of the EPC contractor or the

NSSS supplier (with the training organization transferred to the owner/operator at a suitable point in the project).

The overall schedule for training material development is generally such that work on the commissioning training materials begins 2 to 5 years prior to the scheduled date for fuel loading, with training materials being continually updated/revised as additional information becomes available.

Provided below is information as to when the following publications (suitable for use in training, but often subject to revision/finalization) are generally provided by the construction/project organization:

— System descriptions: (20 to 60 months prior to fuel loading (PTFL)) (median: 33 months)
— System flow diagrams: 20 to 60 months PTFL (median: 39 months)
— System training manuals (if applicable): 20 to 48 months PTFL (median: 30 months) (in some cases system descriptions are used as system training materials, rather than developing separate system training manuals)
— Component operation instructions: 20 to 60 months PTFL, and when components are delivered on–site (median: 30 months)
— Design and construction reports: (18 to 20 months PTFL)
— Commissioning test procedures: (3 months prior to the scheduled date for the test)

2.7. Control room simulator training

Presently, most NPP projects include the provision for a plant-specific, full-scope simulator to be operational 1 year or more prior to fuel loading in order to provide sufficient time for both control room personnel training and verification and validation (V&V) of plant procedures.

For most NPPs now under construction or being planned, I&C systems are digital. For such plants, I&C systems for the plant and the simulator are basically the same. Thus, for these plants, in addition to training, the simulator can also be used to validate I&C system design.

Part task simulators (such as those used to train on I&C equipment surveillances or fuel handling tasks) are increasingly available and can /should be used as well, not to replace full scope control room simulators, but rather to supplement this training.

For all NPP projects, control room simulator training is provided for control room personnel and their supervisors, as well as safety engineers if they are a part of the shift organization. In addition for some NPP projects, control room simulators are also used for other training purposes, including the following positions/groups:

— System engineers
— Instrumentation and control personnel
— Commissioning staff (e.g., leaders of selected tests)
— Regulatory body local inspectors
— Some TSO personnel.

The duration of initial simulator training for operator positions is generally from 4–40 weeks (median: 8 weeks). For other positions: the duration is 1–4 weeks (median: 2 weeks). The simulator training provided for commissioning is often conducted for shift crews as an integrated group.

Integration of the simulator training schedule with the overall commissioning schedule is very important. With the simulator sometimes only available 12 months in advance of fuel loading, the completion of required simulator training for all control room personnel may be on the critical path for commissioning.

Generally, simulator training for a shift is from 4–8 hours per day, with the training time usually divided into a preparatory phase (approx. 2–3 hours in a classroom), practical training (approx. 3–5 hours in the simulator) and evaluation/de-brief (approx. 1 hour, either in the simulator or, if available, in a de-briefing room). During the year prior to initial fuel loading, the control room simulator is often used 12 or 16 hours per day (for two or three groups of personnel per day). If this simulator is also used for training of personnel for another plant (such as a similar unit already in operation on-site), experience has shown it to be a challenge to schedule all required training as well as needed simulator maintenance.

Almost all NPP project organizations use their plant-specific control room simulator for V&V of plant/test procedures (such V&V will be less useful if other than a plant-specific simulator is used). The total hours of simulator time for procedure verification/validation generally varies from 300–600 hours (with a median of 400 hours). This effort also needs to be considered in simulator scheduling/planning.

For a majority of recent NPP projects, a full-scope, plant specific control room simulator was provided by the supplier as part of the plant package.

If an existing control room simulator is planned to be used for training for commissioning, an analysis should be made concerning the differences between the reference plant for the simulator and the plant to be constructed. Based on this analysis the operating organization together with the owner of the simulator can make informed decisions as to how this existing simulator can be modified for the plant being commissioned, or what additional training is needed on the actual plant to address differences between the simulator and the plant. This analysis should also consider the extent to which the existing simulator can be used for procedure V&V and other needs. This analysis should be done early in the project planning phase in order to make an informed decision as to the whether or not a plant-specific full scope simulator needs to be included in the NPP project work scope.

2.8. Training organization for commissioning

Commissioning organization personnel and operating organization personnel are usually trained by the same training organization. This training organization is generally either a branch of the operating organization or TSO, or is a separate organization. In some countries, the training organization is required to have a license for NPP personnel training issued by the Regulatory Body.

For most NPP projects, operating organization personnel for commissioning participate in some or all of the following activities as part of their training/development programmes:

— Preparation of test procedures
— Walk downs of systems and components
— Involvement in turnover inspections

— Observation/participation in commissioning of other projects (either in their home country or abroad)
— Training at manufacturers'/designers' facilities
— On-the-job coaching and mentoring

As indicated in Section 2.4, these activities need to be included in training plans in order to ensure that they are given the needed priority.

If any significant incidents occur during commissioning, a root cause analysis should be conducted. Any training needs identified through this analysis should be addressed and appropriate revisions made in training programmes and materials, consistent with SAT-based training principles. It has become a standard practice for operating NPPs to have a comprehensive experience feedback system to share lessons learned in the industry. Extending this experience feedback system to the design, construction and commissioning phases should be beneficial.

2.9. Use of system engineers

Once the plant is operational, most NPP operating organization use system engineers as the one person to be responsible for the overall health of their assigned plant systems,. Experience has shown that system engineers should be established early in the commissioning phase and be used as part of an integrated team (with designers, commissioning staff and operators) for the development, conduct and evaluation of system tests. The commissioning phase provides an ideal opportunity to establish and develop these system engineers, through assigning them to be the principal interface between the commissioning organization and operating organization for the testing and turnover of their systems. Because of their unique knowledge and experience, these system engineers should also have a role in providing training and training materials (jointly with the training organization), and field support of personnel who will operate and maintain these systems.

2.10. Training of maintenance staff, and other plant personnel during commissioning

The organization established for maintenance during commissioning should ensure that the maintenance group of the operating organization becomes actively involved in the organization and conduct of maintenance during commissioning. This experience is invaluable for training of these personnel.

During the commissioning phase, a complete maintenance training organization should be established and then transition to the operations phase. Maintenance personnel should participate in commissioning testing as well as any maintenance, or post-maintenance testing conducted during this time. Position specific training for maintenance and other plant personnel should also be arranged that combines theory with practice in order to maintain and improve the skills of personnel. Selected maintenance and TSO personnel and related trainers should be provided training by suppliers/vendors on unique maintenance requirements of plant equipment, either at the supplier's facilities or on-site, as appropriate.

It is important to involve maintenance personnel in commissioning activities to develop their competencies in the same way as is done for operations personnel. Commissioning provides one of the best opportunities for development of plant personnel; however, it is necessary to plan to take advantage of these opportunities. Otherwise, competing priorities for the time of these personnel will keep them from benefiting from these unique training/development opportunities.

3. TRAINING AND HUMAN RESOURCE ISSUES FOR SPECIFIC SITUATIONS

This section provides a listing of training and human resource issues that have been identified as being particularly relevant and important for the following situations:

(1) The first NPP in a country or an organization (Section 3.1)
(2) The first of a kind (FOAK) NPP for an existing NPP fleet (Section 3.2)
(3) Rapid expansion of an existing NPP fleet (Section 3.3)

To supplement this information, appendices are included at the end of the publication providing more detailed information regarding training and human resource considerations for selected NPP commissioning projects.

For each of the following sections, the issue is briefly described and then suggested remedies are provided.

3.1. Issues for the first NPP in a country or organization

Issue 1: Understanding and harmonizing plant terminology. Each supplier and vendor has somewhat different terminology applied to its systems and technology. Also, regulatory bodies have often developed their own specialized terminology. At the same time, owner/operator organizations have developed their own terminology in areas such as finance, procurement, training and development, and operations. Collectively, these differences in terminology can cause significant difficulties, particularly for the first NPP in a country or organization.

Suggested remedies: The most successful remedy for this issue is to include, as one of the first steps of the project, the development of a glossary of terms for the project that is agreed to and used by all organizations and individuals participating in the project. For turnkey projects this should be one of the first deliverables provided by the supplier. It should be a living document that is continually updated and maintained under a configuration control programme. In cases where multiple terms are used, or have been used, for the same item, this should be indicated in the glossary.

Issue 2: Common understanding regarding the regulatory framework. Each NPP supplier has developed its own technology; the regulatory framework and approach in the country of origin for the technology have evolved based upon this technology. National regulatory body nuclear safety rules and regulations, while each may be consistent with IAEA Safety Standards, are more detailed, and these rules and regulations have evolved over time as to how the supplier's technology demonstrates compliance with these requirements. In some cases there can be quite significant differences between how suppliers from different countries meet quite similar regulatory requirements. Thus, there is a linkage between a supplier's technology and the associated regulatory framework in the country of origin.

Suggested remedies: If a country initiates a nuclear power programme based upon a particular technology, in order to avoid difficulties in licensing the plant and authorization of plant personnel, it would be useful for the regulatory body in this country to establish and ongoing relationship with the regulatory body in the country of origin of the technology, or with another regulatory body that has experience in licensing plants provided by the selected supplier. Similarly, it would be beneficial for the operating organization to establish a relationship with an organization that is already operating plants of the type to be provided for the project. This relationship should include providing the opportunity for key individuals from the new project to gain experience at a similar NPP.

Issue 3: Competence development for organizations and individuals (e.g. operating organizations, suppliers, and regulators). It isn't realistic to expect that a country or organization initiating a nuclear power programme will, at the beginning, have personnel with all the competencies needed for the programme. There will, most certainly, be a need for assistance in this regard.

Suggested remedies:

— Turnkey projects provide one effective mechanism for developing competencies in these organizations. However, at some point in the project it is necessary that the operating organization take over responsibility for the safe and reliable operation of the plant.
— use of international networks (such as provided by the IAEA) and owners groups
— use of partnerships with suppliers, regulators, and other NPP operating organizations
— partnerships with academic and trade organizations

Issue 4: When education and training programmes should begin to support nuclear power implementation.
The overall plan for nuclear power implementation should include considerations for developing personnel to work in the nuclear power industry. General academic education can begin at any time. However, technology specific training, including plant systems training, needs to await the selection of a supplier. Once this selection is made, this technology related training should begin as soon as possible, in order that the personnel who complete this training can contribute effectively to commissioning activities, and preparations for plant operations.

Suggested remedies:

— involvement of operator personnel in project activities, e.g. design, factory acceptance. Knowledge transfer is needed (not only formal training)
— creation of workgroups for various disciplines (e.g., instrumentation and control, , operators, safety analysis specialists)
— SAT should be adopted as the standard for all training at the earliest stages of the project.
— Relevant training (e.g. formal training on project terminology and standards) should begin before the start of commissioning activities
— Information sharing and benchmarking through international organizations such as the IAEA

Issue 5: Special competencies needed for commissioning, and operation, including:

— overall technical competency (on the plant)
— technical competency for start-up and testing
— administrative competencies (e.g. planning, co-ordination, control, procurement)
— industrial, occupational, radiation and nuclear safety

— quality assurance and quality control

Suggested remedies:

- initial training provided by suppliers
- early development and implementation of administrative procedures for commissioning followed by rigorous change control
- early establishment of standards for organizational behaviors (e.g., professionalism and ethics)

3.2. Specials issues for the FOAK Plant added to an existing fleet

Issue 1: No experienced staff with knowledge of this technology

Suggested remedies:

- Establish relationships with other organizations that are planning projects of the same plant type
- Include in contracts requirements for suppliers to develop and provide initial training, and, in parallel, train operating organization trainers
- Involve research institutes that have experience with this new technology
- Engage other industries that have experience with the new technology

Issue 2: Colleges, universities, and technical schools are not providing an adequate knowledge base for the new technology

Suggested remedies:

- Define the knowledge requirements for graduates
- Define the curriculum requirements for schools
- Define instructional staff requirements to deliver the curriculum
- Develop partnerships with universities and technical schools
- Share resources (simulator, instructors, etc)
- Make potential employees, particularly young people, aware of career opportunities

Issue 3: Validate job and task analyses (JTAs) for existing jobs/positions in view of new technology or conduct new analyses of job positions for the new plant

Suggested remedies:

- Use models from reference plants
- Contract for JTA conduct by experienced consultants
- Focus analyses on duties/tasks/competencies most affected by technology differences between the FOAK plant and existing units

Issue 4: New/revised management system for the new plant

Technology advances have an impact on organization and staffing (e.g. more plant automation implies fewer staff needed). Additionally, each supplier with existing plants in service has expectations regarding organization and staffing for its new plants that were used as the basis for the plant's design and layout. These differences need to be compared to existing structures and processes to determine if revisions to established management systems and processes are needed.

Suggested remedies:

- As early as possible, define information needs and formats for the new plant and compare these to existing methods
- Involve expected users in the revision of management systems and processes
- At the beginning of the project, discuss with the supplier the planned staffing and organization for the new plant, consistent with selected technologies, system designs, and plant layouts.

Issue 5: Need to develop system engineers for nuclear systems

Suggested remedies:

- Utilize reference plants and training materials
- Cooperate with constructor/supplier
- Cooperate with equipment designers/manufacturers
- Practical training by research institutions regarding technologies

Issue 6: Need to train experienced commissioning personnel on new technologies

Suggested remedies:

- Learn as much as possible from a reference plant
- Get these experienced personnel involved in the new NPP project as early as possible, ideally at the beginning.
- Consider the possibility to use (or modify) processes in place for existing units

Issue 7: Terminology differences between existing units (and processes) and the FOAK plant

Suggested remedies:

- Include in the supplier contract, as one of the first tasks, to develop a glossary of terms for the projects that is mutually agreed and endorsed by all project organizations.
- The impact of terminology differences may be higher for support personnel (e.g. radiation, HP, I&C, electricians, instructors etc.) than operators, particularly if these personnel are expected to work at both existing and new units. Thus, provide them with structured opportunities to use/learn this new terminology
- For similar reasons the impact of terminology differences may be high for senior managers. Thus, they may also need structured opportunities to apply this new terminology.

3.3. Special issues for rapid expansion of an existing NPP fleet

Issue 1: Lack of availability of experienced manpower for commissioning or operation of the new NPP units due to the needs of units already in operation

Suggested remedies:

- The NPP project organization should define key positions of commissioning /operation that are required to be staffed by experienced persons
- The NPP operating organization should establish criteria regarding the percentage of experienced persons from the operation and maintenance staff of the operating plants that need to remain in their positions in order to ensure safe and reliable operation of existing facilities.

— The staffing plan for the new NPP project should anticipate recruiting additional staff for existing units (beyond the number needed for safe and reliable operation) several years in advance of when they will be needed for the new plant.

Issue 2: Training materials for existing NPP units may not be suitable for use (as is) for new units.

Due to design changes or other reasons such as:

— changes in equipment suppliers / models / types
— changes in plant process computer systems
— updated I&C systems
— revised seismic design criteria
— new regulatory limits/requirements

Suggested remedies:

— Existing training materials should be used only after a review by the designer / commissioning engineers / suppliers and after necessary modifications.
— Differences manuals should be prepared comparing existing and new plants.
— Configuration management of training materials, particularly for older plants is a challenge (e.g. some materials are in paper form only; tools such as word processing are not sufficient for this purpose). Thus, special emphasis should be on capturing this information in a form where it can be maintained and updated in the future in a manner compatible with that to be used for the new plants.

Issue 3: Acceptance of the authorization of NPP personnel of an existing plant for the new plant

Suggested remedies:

— Early in the project, analyze the differences in plant designs and other factors that are expected to impact the extent to which operators and other plant personnel will be able to work in both existing and new units. Based upon this analysis prepare a proposal to the regulatory body (or other authority in the country that authorizes plant personnel for their assignments) regarding authorization of personnel for the new units.

— The training department, based on agreements with the authorization authority, should prepare training materials specifically designed and developed to qualify previously authorized personnel at other units to be authorized to work at the new units, and to maintain their competencies on all units once they are authorized.

Issue 4: Use of existing control room simulators for the new NPP project

Suggested remedies:

As part of the preparation of the bid invitation package, an analysis should be made regarding control room simulator needs for the new NPP project, including the extent to which existing simulator facilities are both available and will meet these needs. This analysis should include consideration of factors such as:

— Differences in control room designs
— Differences in process computer systems
— Differences in plant system designs, particularly control systems.
— Current and expected demands on existing simulator facilities to meet the needs of operating plants
— manpower / human resource needs and availability for simulator facilities

The work plan for the new NPP project should integrate simulator design and construction (if a new simulator is needed) along with simulator utilization for all intended purposes. If an existing simulator is to be used for some or all of the NPP projects needs, the organization responsible for its maintenance and operation should participate in the development of the work plan.

4. SUMMARY

This publication provides information specific to training and human resource issues for commissioning of NPPs. The body of the publication provides information that should have broad applicability to this topic area, while Appendices II through X provide experiences from specific NPP commissioning activities in several Member States. Additionally, Appendix I, which immediately follows, provides a list of IAEA publications that contain information on training and human resource considerations for NPPs that is complementary to this publication.

APPENDIX I
IAEA PUBLICATIONS RELATED TO TRAINING AND HUMAN RESOURCE CONSIDERATIONS FOR COMMISSIONING OF NPPS

— IAEA Nuclear Energy Series Guide NE-G-3.1, Milestones in Development of a National Infrastructure for Nuclear Power (2007)
— Considerations to Launch a Nuclear Power Programme, IAEA GOV/INF/2007/2 (2007)
— IAEA-TECDOC-1510, Knowledge Management for Nuclear Industry Operating Organizations (2006)
— IAEA-TECDOC-1502, Authorization of nuclear power plant control room personnel: methods and practices with emphases on the use of simulators (2006)
— IAEA-TECDOC-1501, Human Resource Issues Related to an Expanding Nuclear Power Programme, (2006)
IAEA-TECDOC-1500, Guidelines for Upgrade and Modernization of Nuclear Power Plant Training Simulators (2006)
— IAEA Safety Requirement GS-G-3.1, Application of the Management System for Facilities and Activities, (2006)
— STI/PUB/1236, Competency assessments for nuclear industry personnel (2006)
— IAEA-TECDOC-1479, Human performance improvement in organizations: Potential application for the nuclear industry (2005)
— IAEA-TECDOC-1411, Use of control room simulators for training of NPP personnel, (2004)
— IAEA-TECDOC-1392, Development of instructors for NPP personnel training (2004)
— IAEA-TECDOC-1390, Construction and Commissioning Experience of Evolutionary Water Cooled Nuclear Power Plants (2004)
— IAEA-TECDOC-1399, Nuclear Power Industry Ageing Workforce: Transfer of Knowledge to the Next Generation (2004)
— IAEA Safety Guide, NS-G-2.9, Commissioning for Nuclear Power Plants Safety (2003)
— IAEA-TECDOC-1364, Managing human resources in the nuclear power industry: Lessons learned (2003)
— IAEA-TECDOC-1358, Means of evaluation and improving the effectiveness of training of nuclear power plant personnel (2003)
— Safety Standards Series NS-G-2.8, Safety Guide, Recruitment, Qualification and Training of Personnel for Nuclear Power Plants, (2002)
— IAEA-TECDOC-1232, Assuring the Competence of Nuclear Power Plant Contractor Personnel (2001)
— IAEA-TECDOC-1204, A systematic approach to human performance improvement in NPPs: Training Solutions (2001)
— IAEA-TECDOC-1193, Staffing Requirements for Future Small and Medium Reactors (SMRs) Based on Operating Experience and Projections (2001)
— IAEA-TECDOC-1170, Analysis phase of systematic approach to training (SAT) for nuclear power plant personnel (2000)
— IAEA-TECDOC-1057, Experience in the Use of Systematic Approach to Training (SAT) for Nuclear Power Plant Personnel (1998)
— IAEA-TECDOC-1052, Nuclear Power Plant Organization and Staffing for Improved Performance: Lessons Learned (1998)
— IAEA-TECDOC-1024, Selection, Competency Development and Assessment of Nuclear Power Plant Managers (1998)
— Technical Reports Series No. 380, Nuclear Power Plant Personnel Training and its evaluation (1996)

— Technical Reports Series No. 279, Nuclear Power Project Management: A Guidebook (1988)
— Technical Reports Series No. 200, Manpower Development for Nuclear Power: A Guidebook (1980)

APPENDIX II
TRAINING OF PERSONNEL FOR THE COMMISSIONING OF CERNAVODA NPP UNIT 2 (ROMANIA)

1. INTRODUCTION

Nuclear power generation is a reliable source of energy for Romania and an important contributor to the national electricity supply. Romania has one nuclear power plant, Cernavoda, which operates one CANDU 6 reactor, 707 MWe, designed by Atomic Energy of Canada Ltd (AECL). It provides about 10% of the total country electricity generation. The state-owned company responsible for the production and supply of energy from Cernavoda NPP, as well as for its development, is Societatea Nationala "Nuclearelectrica".

The plant was designed to have five similar units. The studies performed for the plant, prior to the construction's start, established feasible technical solutions for all problems related to a 5-units plant, including the environmental impact, which was determined to be entirely acceptable.

Construction of the first unit started in 1980, and units 2-5 in 1982. The pressing problems encountered during construction of Unit 1 (import restrictions, delays etc.) restrained the progress at Unit 2. Starting in 1990, the work on Cernavoda site was focused on Unit 1. Construction at the other units was suspended; during many years; only preservation works were carried-out.

The re-start of work at Unit 2 began in 1995, under the management of the AECL-ANSALDO Consortium. Some work to further construction progress was carried-out (e.g. installation of the fuel channels) and a thorough assessment was performed of the condition of the equipment procured for Unit 2 and stored on site, or already installed. The absence of a clear contractual framework and the lack of resources hindered significant advances in the construction of Unit 2.

Recently, estimates in Romania are that annual electricity production will become insufficient unless Unit 2 of Cernavoda NPP is commissioned. In this environment and considering the relatively low cost of the electricity produced at Unit 1 of Cernavoda NPP versus the energy cost in the conventional thermal stations, the Romanian Government started to provide greater support for the completion of the Cernavoda Unit 2 project.

In the year 2000, the Government decided that completion of Cernavoda Unit 2 was a high priority and supplied part of the financing for it. In May 2001, "Nuclearelectrica" signed a new contract with its traditional partners, AECL and ANSALDO, for the joint management of the construction and commissioning work on Unit 2 Cernavoda NPP. The unit achieved initial criticality in early 2007.

The reference design for Unit 2 is the "as built condition" of Unit 1, with a certain number of improvements. A number of changes are aimed to meet new regulations by providing increased safety margins or improving the reliability of operation in accordance with the development of nuclear technology. Other changes, of a minor nature, will improve system or station performance, or will replace obsolete equipment.

2. STAFFING AND ORGANIZATION

Since July 27, 1998, Societatea Nationala "Nuclearelectrica"(SNN) S.A. reports to the Ministry of Economy and Commerce. The state owns 100% of the shares. "Nuclearelectrica" S.A. produces nuclear-generated electricity, provides district heating and fabricates CANDU 6 type nuclear fuel. The main mission of SNN S.A. is to operate Cernavoda NPP Unit 1 in a competitive, safe and environmentally friendly manner so that the production is optimized and the economic life time of the plant is as long as feasible.

An important function of SNN S.A. is to complete and put into operation the Cernavoda NPP Unit 2 and set-up a "multi-unit" organization on site. According to the contract signed in May 2001, between SNN S.A. and AECL and ANSALDO, the "Management Team", formed by representatives and specialists from Canada - AECL, Italy - ANSALDO and Romania - "Nuclearelectrica" is managing the engineering, procurement, construction and commissioning processes for Cernavoda NPP Unit 2.

More than 1600 workers were employed by the "Management Team," of which 110 were AECL experts from Canada, 80 were ANSALDO employees from Italy and 700 were "Nuclearelectrica" permanent employees. A similar organization was applied successfully for the Unit 1 Project. Their main activities related to Unit 2 commissioning and initial operation are focused on system commissioning, preparation of commissioning procedures and commissioning reports (like Commissioning Completion Assurance Reports), preparation of operating documentation, and assessment of documents (such as Plant History Documents).

3. RECRUITMENT OF U2 COMMISSIONING STAFF

The Unit 2 commissioning staff recruitment process was based on two sources:

- Recruitments from outside of SNN S.A.;
- Transfer from Cernavoda NPP Unit 1.

A source for recruitment from outside of SNN S.A. is graduates of the Bucharest Polytechnic University, especially from the Nuclear Power Faculty. SNN maintains close relations with the Bucharest Polytechnic University and has financed several scholarships for students each year. After graduation, these students have started to work as permanent employees at the Cernavoda NPP.

About 100 experienced employees were transferred from Unit 1 to support Unit 2 commissioning and operation. Their experience was gained during Unit 1 systems commissioning, system operations, preparation of commissioning procedures, technical information reports, commissioning reports, etc. All of them have been trained within the Cernavoda NPP Training Department. Also, many of them have been trained in specific job functions for Unit 1 commissioning and operation by assignments to the Point Lepreau station in Canada during 1992 / 1993.

Control Room Operators and Shift Supervisors have been recruited from the Unit 1 operation staff. Also, a number of non-licensed operation positions were filled with experienced nuclear operators from Unit 1.

A ratio of experienced / inexperienced personnel of about 1:3, was established with the commissioning organization based on:

— the operating units needs;
— the experience / training needed for commissioning role.

4. COMMISSIONING TRAINING PROGRAMMES

According to the Cernavoda NPP training policy, Unit 2 commissioning staff shall be qualified for the tasks they are expected to perform. Training programmes are performance based and linked directly to tasks that an individual is expected to perform as part of his job.

Training programmes for Unit 2 commissioning personnel are based on SAT principles and address the essential capabilities and qualifications to support plant commissioning and operations. Personnel from the operating organization (operators, maintainers, system engineers) were included in the commissioning training programmes.

Training needs for Unit 2 personnel have been identified based on Table Top Analysis performed for similar jobs from Unit 1 of the Cernavoda NPP.

The required level of qualification and experience is specified for each position in the organization.

Basic training materials were prepared well in advance compared to the commissioning schedule. Because Unit 2 is the same basic design as Unit 1, the Unit 1 training materials have been used for training of Unit 2 commissioning personnel. For design differences, specific training materials were prepared before any commissioning activities began.

Training programme implementation started in 2002, with first 250 persons hired for commissioning and operation.

As of 2007, for commissioning and operation of U2, about 350 persons were trained within the Cernavoda NPP Training Department and Unit 1 facilities. Also, for the Unit 2 commissioning training programmes, lecturers from "Ovidius" University- Constanta and Bucharest Polytechnic University were involved. These personnel were scheduled to be trained in 5 batches, based upon the activities they were assigned in commissioning and the duration of training.

Initial training

Initial training for Unit 2 commissioning personnel included 2 main parts:

— General technical nuclear training programme;
— On-the-job training programme.

The general technical nuclear training programme consisted of the following topics:

— Orientation - a generic programme provided to all new employees in order to familiarize them with the plant, its physical layout, the basis of plant operation, station organization, and administrative procedures which govern its day-to-day operation. In addition, the programme provides an introduction to both conventional and nuclear safety, the quality assurance programme, the requirements for radiation protection and actions in the event of an emergency situation on site;

— Industrial safety - a programme which provides staff with the required safety awareness and safety knowledge appropriate to their job duties;
— Science fundamentals and nuclear technologies - courses intended to provide plant staff with the knowledge to enable understanding of the principles of plant systems and equipment operation;
— Plant systems training - provides a technical understanding of major plant systems in both the nuclear and the conventional areas.

On-the-job training programme is based on job specific courses and activities in order to provide:

— Specific knowledge and skills for a particular job;
— Familiarization with reference documents, station instructions and work procedures that refer to a particular job;
— Specific training on design differences between Unit 1 and Unit 2.

In order to meet the licensing requirements, experienced and qualified staff from Unit 1 fill the Unit 2 Control Room Operator and Shift Supervisor positions.

Licensing Training Programmes were developed for Shift Supervisors and Control Room Operators. The Licensing Training Programme prerequisite for Shift Supervisors is a valid license from a similar unit (in our case Unit 1), and for Control Room Operators, at least completing the Initial Training Programme for Unit 1.

Five Unit 1 Licensed Shift Supervisors and 13 Control Room Operators started the Licensing Training Programme to obtain a Unit 2 operating license.

The development of the licensing training programme was SAT based and was preceded by the identification of the differences between Unit 1 and Unit 2 in terms of equipment and system functions using design manuals, operating manuals, and system flowsheets, etc., as references. Then, the operator tasks affected by the differences were identified and analyzed to identify required training. This process started 2 years before scheduled first manual fuel load.

The operator licensing training programme has been focused on:

— System specific training on design differences between Unit 1 and Unit 2. The duration of the training is 1 month.
— Simulator training on operator response to major transients and abnormal operating procedures, followed-up by an internal and regulatory body practical evaluation before the Manual Fuel Load. The duration of the training is 4 months, both for Shift Supervisors and Control Room Operators.
— Practical training related to Unit 2 Control Room panel configuration, systems test and operation in commissioning phase.

The training programme for Unit 2 field operators utilizes the training and experience gained through Unit 1 operator training. On-the-job training covers essential operator skills and elementary system knowledge.

A main part of the on-the-job training programme for field operators has been carried-out by the Unit 1 Operation Department, under the guidance of experienced operators, using existing training materials. In addition, the training programme has included training on design differences between Unit 1 and Unit 2, for which training materials were developed.

Also, an emergency response training programme was developed and implemented for response team operators in order to develop skills and capabilities to respond to emergency plant situations (chemical spills, fire, medical incidents, and radiation events).

The Unit 1 full-scope simulator is used for Unit 2 operator simulator training. The differences between Unit 1 and Unit 2 were analyzed and documented. Base on this, during the training development phase, the tasks that were impacted by the differences were identified and suitable training methods were built into the programme. The licensed operator training programme includes simulator training, training on mock-ups, walk through training and on the job training.

The simulator was required to be operational for Unit 2, 1 year before scheduled first fuel load in order to allow the development of simulator training programmes for licensed staff and to conduct licensing training for the operators. The simulator was mainly used for the training of licensed personnel and operators who are part of the emergency response team. Also, the simulator is used for licensed personnel examination by the regulatory body.

Based on their commissioning responsibilities, the duration of commissioning training programmes is:

— 2 to 3 years for system engineers;
— 3 to 4 years for operating personnel (operators, maintainers, fuel handling personnel).

The completion of commissioning training is a mandatory qualification requirement for commissioning personnel before being assigned to the commissioning team.

The licensed operator training programme was approved by the regulatory body. Also, the regulatory body monitored all commissioning personnel training. During training implementation, they audited training activities.

Continuing training

The purpose of Unit 2 commissioning and operation personnel continuing training is to maintain and improve job performance and to develop position-specific knowledge and skills.

The continuing training programme covers requalification for any qualifications that have a specified lifetime, refresher training to maintain and improve skills, industry operating experience, performance problems, plant system/equipment modifications and procedure changes, and identified weaknesses in training content or delivery.

APPENDIX III
OLKILUOTO 3 NUCLEAR POWER PLANT TRAINING AND HR ISSUES FROM THE NPP OPERATING ORGANIZATION PERSPECTIVE (FINLAND)

1. INTRODUCTION — NUCLEAR POWER IN FINLAND

About one fourth of all energy consumed in Finland is generated utilising nuclear power. There are two nuclear power plants in Finland, with a total of four plant units: the Olkiluoto power plant owned by TVO and the Loviisa power plant owned by Fortum Power and Heat Oy. The reactors in the Loviisa plant are pressurised water reactors (PWR) supplied by the Russian Atomenergoexport, while the Olkiluoto plant operates boiling water reactors (BWR) supplied by the Swedish Asea-Atom.

The Finnish nuclear power plants have been in operation already from the late 1970s. Both plants have maintained world-class capacity factors and operating reliability throughout their operation.

2. THE NEW NUCLEAR POWER PLANT UNIT — OLKILUOTO 3 (OL3)

The French-German Consortium formed by AREVA NP and Siemens AG has the total responsibility for the construction of the Olkiluoto 3 plant unit, with AREVA NP in charge of the reactor plant and Siemens of the turbine plant.

The reactor selected for Olkiluoto 3 is the European Pressurised Water Reactor (EPR). The electric output of the plant unit is approximately 1600 MW. The design technical service life of the plant unit is 60 years.

Olkiluoto 3 meets all the Finnish and international safety requirements laid down for nuclear power plants. In Finland, the general principles of nuclear safety are presented by the government. The detailed instructions for the application of the safety requirements are drawn up by STUK, Radiation and Nuclear Safety Authority of Finland, which also controls compliance with the requirements.

3. ORGANIZATION OF TEOLLISUUDEN VOIMA OY (TVO)

Teollisuuden Voima Oy (TVO) was founded on January 23, 1969 by 16 Finnish industrial and power companies. The operating principle of the Company is to supply electricity at cost price to the shareholders, as safely, reliably and economically as possible.

The basic organization of the Company on 1 January 2005 is shown in Figure 1.

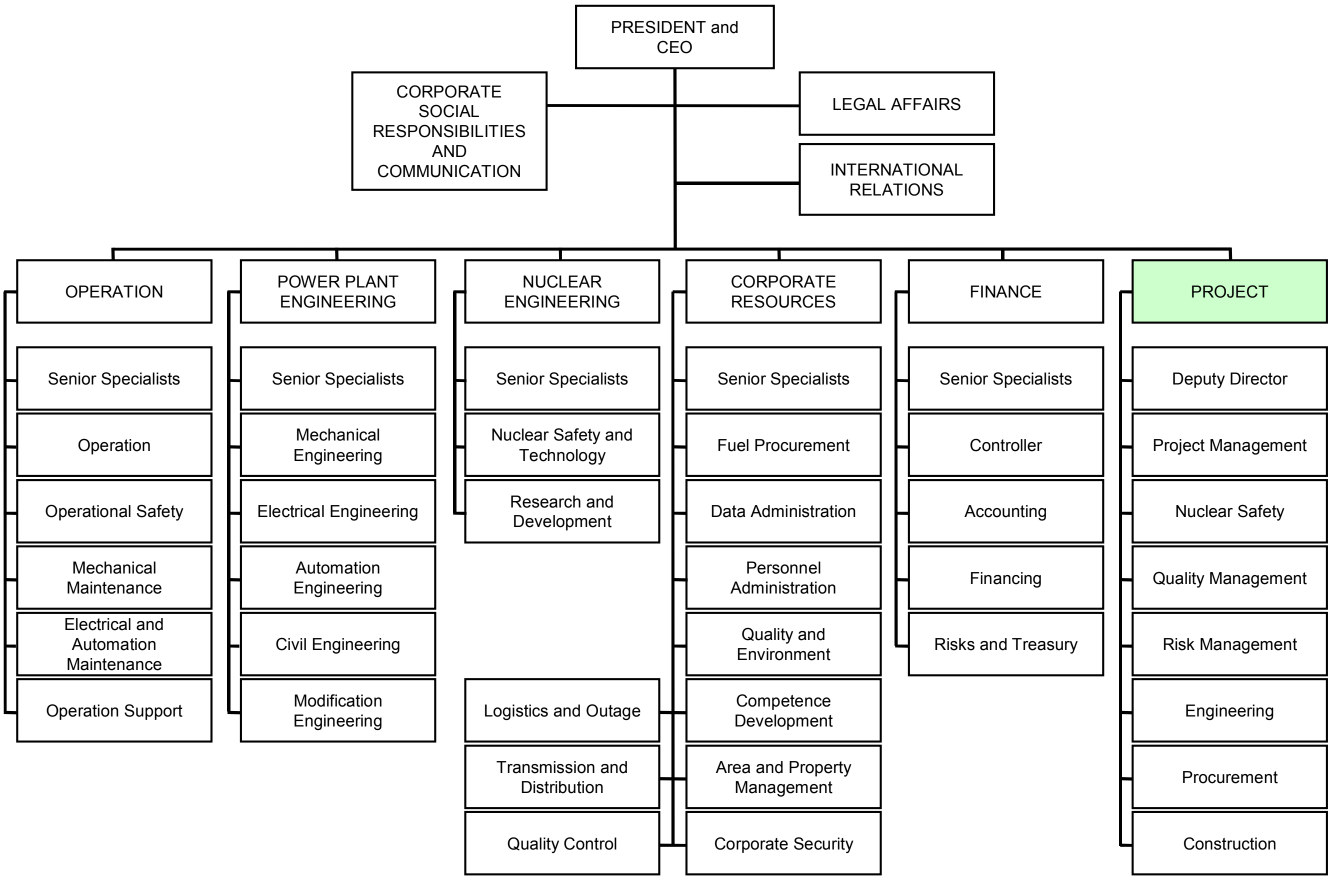


Figure 1. TVO organization.

4. STAFFING PLANS FOR COMMISSIONING

4.1. Grounds for the TVO commissioning organization

The organization of TVO for the commissioning of OL3 is based on the organizations of the Project Department and the Operation Department. During the construction project of the Olkiluoto 3 plant unit, i.e. prior to the granting of the operating licence, responsibility for all activities taking place at the plant rests with the Director of the Project Department, and with the Department headed by him. The Nuclear Safety Division of the Project Department is responsible for safety, particularly during the construction project of Olkiluoto 3.

However, the Director of the Operation Department and the Operation Department are responsible for activities related to the handling of nuclear fuel as well as for activities carried out during the trial operation period already before the operating licence has been granted.

After the operating licence for the nuclear plant has been granted, the Director of the Operation Department and the Department that he heads are responsible for all safety related activities carried out at the plant.

The Departments of Corporate Resources, Nuclear Engineering and Power Plant Engineering support the commissioning organization by participating in a separately agreed manner in the implementation of the commissioning stage. The Legal Department, the Finance Department and the Social Responsibility and Communication Department are involved in the same manner.

The TUVA project (Preparation for the production phase) is divided into sub-areas, with the sub-area "Organising of production operation and control of staff recruiting" responsible for defining in compliance with a specific action plan the organization required for the new plant unit, and the operating strategy of the unit. The organization responsible for this sub-area is the Operation Department and the responsible coordinator is the Director of the Operation Department. The planning of the operation organization for the new plant unit was started well before the construction licence for the unit had been granted (2/2005). The preliminary plans were published in 2003. Recruiting of operating staff started in the spring/summer of 2004, when the first Shift Supervisors, operators and operation planners were recruited. Key appointments for positions in areas that provide technical support to operation, such as chemistry and radiation protection, were made in 2004. The recruiting of maintenance staff started in 2005.

The operation activities of the new nuclear power plant unit and also OL1/2 unit will be combined with the existing organization. In order to ensure that a sufficient number of personnel are recruited already at the plant construction and installation stage for the commissioning and operation of the new unit, the existing organization is used as the basis for organising the activities. Apart from recruitment of new employees, vacancies are filled also through internal transfers between Olkiluoto 1/Olkiluoto 2 and Olkiluoto 3, and experience gained during the project stage will become available for the operation organization when the project organization is no longer required.

For the operation of the OL3, a separate section has been established. Activities related to asset management, operation support and operational safety are secured by reinforcing the existing organizational units.

A common terminology bank will be established to facilitate the commissioning process and coming operation of OL3. The purpose of the bank is to ensure that everybody involved in the commissioning process uses the same terminology.

5. COMMISSIONING TRAINING PLAN DEVELOPMENT AND CONTENT FOR COMMISSIONING TRAINING

The planning of training to be provided to the members of the commissioning organization will be implemented in cooperation with the commissioning function. Commissioning training will be provided to everybody involved in the commissioning of the OL3 plant. The objective of this training is to familiarize personnel with the documents that provide the basis on which commissioning is implemented (Commissioning Manual and Commissioning Plan) and to describe the commissioning organization, the regulatory stipulations, the administrative procedures and responsibilities. Training is divided into training provided by the plant supplier and training provided by TVO. The following personnel groups involved in the commissioning process are taken into account in the plan.

- Operation Department and Project Department personnel involved in commissioning
- Personnel of support organizations involved in commissioning.

A joint emergency preparedness exercise with the authorities shall also be organised prior to the commissioning of the new nuclear power plant unit.

The plant supplier is responsible for providing training at the commissioning stage to operators, to asset management and to operation support.

The planning of training to be provided to the personnel of the installation supervision organization has been started. Training is planned in cooperation with the coordinators responsible for installation supervision. A more detailed daily training plan is developed as a separate document.

6. CONTROL ROOM SIMULATOR TRAINING TO SUPPORT COMMISSIONING

Simulator training supports commissioning by increasing the capability of the operators to operate the plant systems and the entire plant during the commissioning process. Simulator training can also be utilised to verify and validate system and plant specific specifications and instructions that can later be used also during the commissioning process.

The commissioning function also influences simulator training, as commissioning trials will disclose many situations that the operators should practice on a simulator before working at the plant. It is possible that some of the simulator instructors of the plant supplier will be engaged in the commissioning process, which will ensure swift transfer of data from the plant to the simulator.

7. SPECIALS ISSUES FOR THE FOAK PLANT ADDED TO AN EXISTING FLEET

7.1. Assessment of data systems

The new plant unit will introduce a tremendous amount of data that need to be considered in the development of data systems. Existing operating procedures and data systems are designed to be sufficiently comprehensive in terms of both functions and data, to make it possible to utilise them also in the control of OL3 operation. TVO has made an assessment of how the adaptation of the existing data systems to the needs of Olkiluoto 3 can be implemented. The systems were assessed with respect to their functionality, need for building new modules, and capability of receiving the required amount of data. The assessments were used as the basis for determining the modifications to be implemented in the different systems.

The following criteria were utilised in the assessment:

— The data systems in which structural data submitted (primarily by electronic transmission) by the plant supplier will be stored shall be identified.
— The areas of operation in which operating procedures and the supporting data systems need to be significantly modified shall be identified (i.e. data systems shall support the new procedures).
— The areas on which a significant amount of new data will be stored in data systems by TVO's own personnel in connection with the commissioning of the new plant shall be identified

7.2. Acquisition of new technical expertise

New plant technology entails the challenge of teaching it. For Olkiluoto 3, practical training for operators is provided at reference plants in Germany and France. The plant supplier produced theoretical training. TVO has trained its personnel in compliance with TVO's own position-specific training requirements, utilising also Finnish universities. Information sharing with the Loviisa pressurised water plant also played a significant role.

7.3. Preparation of Job Tasks Analyses (JTA)

The JTAs of Olkiluoto 3 operators were based on the JTAs of Olkiluoto 1/2 personnel, taking Olkiluoto 3 specific procedures into consideration. The JTAs of other personnel were based on IAEA's model as well as on JTAs used at other, existing plants.

APPENDIX IV
TRAINING OF MANPOWER FOR COMMISSIONING PROJECTS
TAPP-3&4- A CASE STUDY (INDIA)

1. INTRODUCTION TO NPCIL

Nuclear Power Corporation of India Limited (NPCIL), wholly owned by the Indian Government, is responsible for the design, construction, commissioning and operation of nuclear power plants (NPPs) in India. NPCIL owns sixteen operating power plants. NPCIL is currently building six NPP units. The Atomic Energy Regulatory Board (AERB) is the independent regulatory body for NPPs in India. NPCIL understands that training and development of manpower is vital to its success and has an integrated approach for training of its personnel. It is important to first explain the NPCIL organization for a new project before discussing training programmes for project staff in the commissioning organization.

2. PROJECT CONSTRUCTION ORGANIZATION

Project construction groups of NPCIL undertake construction and installation through departmental agencies, equipment suppliers and contractors. The quality surveillance of plant construction is the responsibility of the QA group at the plant site, with periodic audits by NPCIL Headquarters.

The field-engineering organization on site is responsible for overseeing the fulfillment of design intent during construction and commissioning stages in areas engineered by the design group of NPCIL. Similar functions for the conventional area rest with the resident engineers of consultants stationed at the project site. A typical overall organization chart for a new NPP project is given in Annexure-1.

3. PROJECT COMMISSIONING ORGANIZATION

Responsibility for NPP commissioning activities is entrusted to a commissioning team formed out of operations and maintenance (O & M) headed by a Station Director who possesses experience in commissioning and operation of nuclear power plants. A typical site organization chart is given in Annexure 2. The engineers-in-charge of commissioning are guided by field-engineers, Station Director, and the NPCIL design group, in the commissioning of systems and in interpreting the design intent. Assistance is provided by engineers from the NPCIL design group, or from supplier's/manufacturer's engineers, as appropriate. Individual equipment suppliers as well as contractors are entrusted with the responsibility for installation and testing their equipments, as prerequisites for system commissioning tests. Prospective operations and maintenance personnel for the plant are involved in commissioning activities in order to gain valuable experience.

4. ROLE OF COMMISSIONING GROUPS

A top level team from the commissioning organization prepares the Tier-I documents, drawings, and references based upon regulatory safety guides, safety analysis reports and past experience. Well before the field commissioning activities begin, the individual commissioning groups prepare Tier-II documents for their systems and ensure such documents are made available to all other commissioning groups. A typical list of such document is provided in Table-1.

TABLE 1. DOCUMENTATION PREPARED DURING COMMISSIONING

Documentation prepared by the top level team in the commissioning organization	**Typical numbers**	
Station Norms	22	**Tier-I documents**
Regulatory submissions for various stages of commissioning	7	
Master commissioning network	1	
Documentation prepared by commissioning groups		**Tier-II documents**
Commissioning Procedures (Vetting done by NPCIL Designer)	369	Documents required for Commissioning
Equipment level maintenance procedures	337	
Commissioning reports (Concurrence by NPCIL designer and review by Regulatory body)	369	
Operational flow sheets	195	Documents required for Plant operation
Operating manuals	175	
Operating procedure checklists	300	
Surveillance test procedures	120	
Emergency Operating Procedures (in collaboration with NPCIL Designer and safety analysis group)	62	
Training Manuals	41	Documents required for O & M training
SAT based checklist for station licensing programme	-	

A joint team from design, safety analysis and commissioning organizations develops the technical specifications for plant operation.

Based on the Station Level Zero Corporate Plan of Activities from Construction to Commercial Operation of the Plant, commissioning groups are required to develop detailed schedules of activities, monitor progress, and provide inputs to the Planning, Construction and Procurement Department. Commissioning groups are responsible for deficiency monitoring and corrective action programmes.

Once auxiliary systems are commissioned, these are transferred to the O & M group, which operates them to meet requirements for commissioning and operation.

Macro-level commissioning involving the entire commissioning organization is divided into the following phases.

Phase A – Pre operational and commissioning tests including hot conditioning, fuel loading and bulk addition of heavy water.
Phase B – Initial approach to first criticality and low power physics experiments.
Phase C – Initial system performance tests at low, medium and rated power levels, and overall plant performance tests at rated power level.

5. RECRUITMENT FOR COMMISSIONING

In order to perform commissioning responsibilities as outlined earlier, members of the commissioning organization are drawn from the following sources:

(1) Other NPP Stations
(2) Construction
(3) Fresh Recruits

Other NPP Stations: The key positions for commissioning, which include system-commissioning engineers, and equipment-commissioning engineers of maintenance units, are identified and transferred from other stations of NPCIL. This number varies depending on factors such as availability of manpower and the number of units planned for commissioning. The typical range is 50-100. These experienced persons are identified to take future key O&M positions after commissioning including Shift In charge and Assistant Shift In charge in operations.

Construction: Some of the positions at the junior level, such as drawing office; field engineering, IT, QA and some maintenance staff are drawn from the construction organization. The typical range is 40-80.

Fresh Recruits: the additional team members are drawn from fresh recruitment and are imparted training as per the programme detailed in the next section.

6. TRAINING FOR COMMISSIONING

All the fresh recruitments are done at three entry levels and are imparted foundation training, which includes classroom, as well as on-the-job training. Table-2 details the period of training for the various categories of fresh recruits.

TABLE 2. FOUNDATION TRAINING FOR FRESH RECRUITS

Entry Streams	**Qualification at the time of recruitment**	**Classroom training**	**On-the-Job Training**
Executive Level Induction Training	Graduate in Eng./Post graduate in basic science	Six months theoretical	Six months on the Job
Supervisor Level Induction Training	Diploma in Eng./Graduate in basic science	Six months theoretical	1 year on the job
Tradesmen Level Induction Training	Secondary School Certificate/Industrial training certificate	Six months theoretical	1½ years on the job

6.1 Executive Level Training:

This training comprises general principle of NPPs, specific system details, general principles of radiation protection, station procedures, fire safety and industrial safety practices and procedures, and general engineering connected with power engineering such as thermal engineering, electronic logic and instrumentation, electrical engineering and relay protection.

The six months on the job training includes working as Trainee Executives at an operating NPP in various departments including Operation and Maintenance.

On completion of executive training and on joining the commissioning group, the Executives are given check sheets involving details of various tasks including theoretical and field based questions. These check sheets are based on the Systematic Approach to Training (SAT). All the executives are asked to work further as trainee executives in operation of other plants and are additionally provided simulator training on various plant startup/shutdown procedures. Generally simulator training is provided after the executives complete observations in the field pertaining to systems as per SAT based check sheets. For some executives the training also includes their placement in the commissioning group of a plant, that is under going commissioning.

Executive trainees are expected to complete their field engineer training modules under level III qualified persons in operations. If their trainee assignment includes commissioning they work under system commissioning engineers and in the maintenance department under level III qualified maintenance engineers.

Upon completion of the two-year training period they are expected to take level III qualification either in Operations or Maintenance and assume a role of system commissioning engineer, control engineers (Control room plant operator), or system maintenance engineers.

6.2. Supervisor Level Training:

Supervisor level training is based on plant systems. The theoretical engineering component is less than for executives, with more emphasis on plant practices and procedures. Fire, industrial safety, health physics and station protection codes are part of the curriculum. All commissioning engineers, upon completing the two year training period, are expected to acquire a level III license.

Upon completion of six months training they are placed for 1 year as trainee supervisors to actually work and supervise operating reactors. After completion of theoretical training, the department in which the supervisor will work is identified. All commissioning supervisors upon completion of the two year training period are expected to acquire a level IV license.

Upon completion of training, supervisors are placed in the unit under commissioning for further assignment. They are given a level IV qualification check sheet which they are expected to complete within the next six years.

6.3. Operator/Technician Level Training:

Individuals are identified at the start of training as either trainee operators, or trainee technicians for various maintenance units. Theoretical training includes details of various plant systems and specific training modules on the various plant departments. Subsequently they are trained in an operating plant for a period of 1½ years.

7. TRAINING DURING COMMISSIONING

The training programme for the commissioning staff not only covers the commissioning organization but also the construction staff including those of contractors. This has become important as parallel-commissioning activities are to be carried out in some of the systems (or even parts of the system) even while construction activities are in underway on other systems and buildings. Such situations demand knowledge of each other's work practices between construction and commissioning personnel. The training requirement is tailor made to suit the functional requirement of each of the work groups outlined in Table 3.

TABLE 3. TRAINING FOR COMMISSIONING PERSONNEL

<table>
<tr><th>Senior Managerial position</th><th>Junior Managerial position/Executives</th><th>Supervisors and Field Operators/Tradesmen</th><th>Contractors</th></tr>
<tr><td>Training lectures on regulatory safety guides</td><td>System design lectures</td><td>System familiarization lectures</td><td>Industrial safety lectures</td></tr>
<tr><td>Twice a week system familiarization lectures</td><td>Twice a week system familiarization lectures</td><td>Trade skill development training modules in the functional area.</td><td>Do's & Don'ts in the work permit system</td></tr>
<tr><td>Technical Specifications for operation in symposia</td><td>Station procedures governing work permit system</td><td>Station procedures governing work permit system</td><td>Do's & Don'ts in radiological work practices</td></tr>
<tr><td>Training on first approach to criticality</td><td>Training on configuration control procedures</td><td>Training on configuration control procedures</td><td>Radiological emergency drills</td></tr>
<tr><td>Management development training</td><td>Management development training</td><td>Equipment level familiarization lecture by equipment suppliers</td><td rowspan="10">Daily pep talk on industrial safety.</td></tr>
<tr><td>Station norms in symposia</td><td>Radiological protection training</td><td>Radiological protection training</td></tr>
<tr><td rowspan="8">Briefing on site specific contracts</td><td>Fire fighting training</td><td>Fire fighting training</td></tr>
<tr><td>Industrial safety training</td><td>Industrial safety training</td></tr>
<tr><td>Commissioning/Operating experience seminars</td><td rowspan="2">Quality circle seminars</td></tr>
<tr><td>Simulator practice</td></tr>
<tr><td>SAT based checklist</td><td>SAT based checklist</td></tr>
<tr><td>Electrical authorization</td><td rowspan="3">Electrical authorization</td></tr>
<tr><td>Technical Specifications for operation in symposia</td></tr>
<tr><td>Training on first approach to criticality</td></tr>
</table>

For senior level positions the training programme is designed for development of conceptual skills on various intricacies of a project under commissioning and about to be converted to an operating nuclear power plant. The manpower deployment scheduling is done in such a way that the senior level team is placed on site at least two years before the scheduled criticality of the first unit. They are responsible for planning of all the resources including manpower, budget for commissioning and optimization of the commissioning schedules. Details of further deployment of manpower are given in Table 4. Executives are responsible to carryout the micro level plan and to align their organizational unit's output to the overall project schedule. This necessitates inter-group training of all commissioning engineers. An interactive training programme, based on a mutual training concept among the commissioning groups, is arranged wherein each commissioning group imparts knowledge regarding their work area to other commissioning groups. Additionally, executives, supervisors and other staff are required to transition to licensed plant operation and maintenance positions from their posts in the commissioning team. This requires highly demanding work and training schedules. Emphasis is placed on building up detailed knowledge and a high level of competency in their work areas. SAT-based checklists and simulator training are included as part of the licensing/authorization process.

8. RESULTS AND LESSONS LEARNED AT TAPP-3&4:

(1) TAPP-3&4 is India's first 540 MWe PHWR NPP. It is also a first of a kind (FOAK) reactor design. From first pour of concrete to the criticality of the first Unit (TAPP-4) it has taken less than five years which is an Indian bench mark, for a FOAK reactor.
(2) With the commercial operation of the second unit the project could be completed in less than 6.5 years. This will be achieved with a large number of design changes, midcourse corrections and procedural changes under taken by a group of O&M engineers & technical staff of about 600 plus about 250 construction engineers. Their motivation and technical competency and managerial prowess have been developed by an appropriate training programme.
(3) The training programme on the plant design has helped in better understanding of plant systems, which has resulted in over 1000 modifications by the commissioning group.
(4) A trained and knowledgeable team created commissioning documents, which are operator friendly and have contributed to an event free commissioning.
(5) Commissioning was preformed in less time than originally planned. In a rapidly changing environment, large amounts of information are produced during commissioning and construction. To update all the affected staff, briefings on salient highlights of the systems are arranged during daily meetings.
(6) At TAPP-4 during commissioning and operation, rich experience was gained which was passed on to the commissioning and operation team for TAPP-3 through written documents and interactive discussions.
(7) Performance of the plant after commissioning has been satisfactory.

TABLE 4 . MANPOWER DEPLOYMENT DURING COMMISSIONING

1ST STAGE — **2 quarters**	**2ND STAGE** — **4 quarters**
Preparation of different documents, Norms, FS, Training Manuals, Operating Manuals, Commissioning Procedures, Maintenance Procedures. Identification of vendors, Identification of machines, Material and consumables. Identification establishment of machine shop, VTF, RT Lab, Storages, Calibration Shop (CMU), Welding shop, Chemical lab, FHS shops, HPU Lab. Commissioning of D.M. plants. Preparation of level 1 & 2 commissioning plans Engineers : 40–60 Supervisors : 20–30 Technicians : 10–20	Commissioning of Fire water & deluge system. Charging of SUT. Commissioning of Electrical Systems. Commissioning of Water system. Commissioning of compressed air system. Commissioning of part of ventilation system. Completion of infrastructure set-ups by various sections. Completion of commissioning documents, Training & qualification check lists. Pre-commissioning checks of Nuclear system & air hold test etc. Commissioning of DGs. Engineers : 60–80 Supervisors : 80–100 Technicians : About 200

3RD STAGE **3 quarters**

Flushing of major systems.

PHT hydrotest.

Commissioning of Moderator System & Reactor Auxiliary System.

Commissioning of Feed Water System.

Commissioning of ECC system integrated test.

Commissioning of RB proof test & ILRT test.

PHT Hot conditioning.

Draining & drying of PHT. Fuel loading.

D_2O bulk addition in Moderator system.

Commencement of licensing programmes.

TAPP#3

Early stage commissioning of SUT charging, commissioning of water systems etc.

Engineers	:	90-120
Supervisors	:	120-150
Technical	:	340-380

4TH STAGE **3 quarters**

First approach to critically, Phase – B. Experiments.

TG systems Commissioning.

Reactor power raising.

Vacuum pulling, Turbine & Generator tests.

TG Synchronization.

Net load & Gross load rejection test.

Commercial operation.

TAPP#3

Flushing of major systems, PHT hydrotest.

Commissioning Moderator system + Reactor auxiliary system.

Commissioning of feed water system.

ECC system integrated test.

RB proof test, ILRT test & FH systems commissioning.

PHT Hot conditioning, Draining & drying fuel loading.

1st approach to criticality

Engineers	:	130-150
Supervisors	:	160-180
Technical	:	460-480

Additional manpower up to 25% extra from other station for TAPP-3 commissioning.

APPENDIX V
SHIN WOLSONG CONSTRUCTION AND COMMISSIONING, TRAINING IN KHNP (ROK)

1. INTRODUCTION

Since the excavation of the reactor building foundation of Kori Unit 1 in November 1971, ROK has achieved rapid growth, and now has 20 operating nuclear units, 4 units under construction.

The ROK's outstanding development in the nuclear power industry over the last 30 years shows not only growth in the number of the nuclear units and installed capacity, but the persistent consensus among ROK's government, nuclear industries, and the people to cultivate our formerly vulnerable nuclear environment, to introduce new nuclear technology from abroad and to develop and secure our own nuclear technology.

As a result of these efforts, ROK secured the Korean Standard Nuclear Power Plant (KSNP) model and has been successfully making progress in the development of the Improved KSNP (KSNP+), in so doing, enhancing the position of ROK nuclear technology in the world.

With Shin Kori 1 & 2 being under construction, Shin Wolsong 1 &2 are the improved KSNPs (KSNP+) that has been implemented to enhance KSNP technology and economic competitiveness by utilizing innovative and comprehensive design improvements based on new construction technology and operating experience feedback.

This Shin Wolsong1&2, started in Oct. 2005, are scheduled to begin commercial operation in 2011 and 2012, respectively.

TABLE 1. ROK NUCLEAR POWER PLANTS UNDER CONSTRUCTION

plant		reactor type	capacity (MW)	commercial operation	remarks
Shin-Kori	#1 #2	PWR PWR	1,000 1,000	Sep. 2009 Sep. 2010	$KSNP^+$ $KSNP^+$
Shin-Wolsong	#1 #2	PWR PWR	1,000 1,000	Sep. 2011 Sep. 2012	$KSNP^+$ $KSNP^+$

KSNP : Korea Standard Nuclear Plant

2. GENERAL

(A) Design features of KSNP
1. 2 loop RCS design
2. Power level : 1,050/2,825 MWt
3. Plant Design Life : 40 years
4. Plant Availability (Target Value): 80~87%
5. Advanced Design Features
    — Human factors engineering
    — Design against severe accidents
    — Leak before break(LBB) concept

— Increased operability and maintainability
— Lower occupational radiation exposure

(B) Improved KSNP (KSNP+) features

(1) Plant and Equipment Arrangement Optimization

— Reduction of the building volume and construction material quantity

(2) Equipment capacity optimization and new technology

— Minimized capacity of emergency DG, various pumps and Aux. boiler
— Application of Passive Automatic Recombiner for Hydrogen Concentration Control System
— Application of Steel-Concrete Composite Structure and Deck Plate

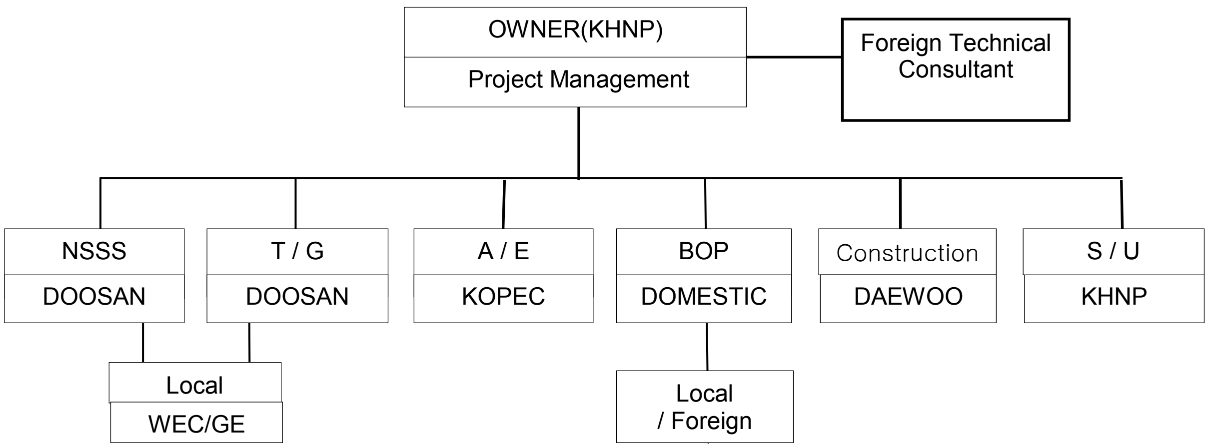
(3) Improved operation and maintenance convenience

— Integrated Reactor Vessel Head Assembly
— Equalization of each floor level for Aux. Bldg, Reactor Bldg, Fuel Bldg and Common Bldg.

3. CONSTRUCTION STAFFING AND ORGANIZATION

Initial staffing for Shin Wolsong in key positions are experienced personnel from Ulchin and Yonggwang plants. Based on experience from previous KHNP projects, additional positions will be filled with young people who are recent graduates of universities and technical schools. The staffing sizes for each phase are determined based on the activities that are on the critical path of project schedule.

The organization of the project and the scope of supply are follows



4. CONSTRUCTION SCHEDULE

Category	Duration	Milestone					
		1st Con	Rx Install	CHT	HFT	F/L	Commercial Operation
Standard schedule	60 months	0~23	24~45	46~48	49~52	53~60	60
Ulchin#5	56 months	0~20	21~40	41~44	45~48	49~56	56
Shin Wolsong	53 months	0~20	21~38	39~42	43~46	47~53	53

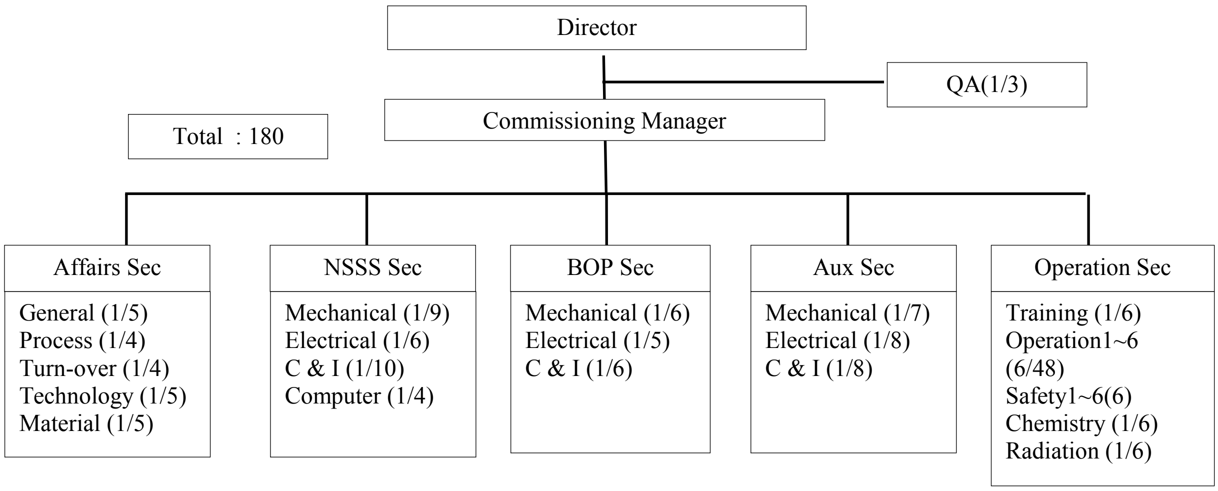
5. MAJOR MILESTONES

- 1st concrete : 2007. 06.01
- Reactor installation: 2009. 02.01
- Initial power supply : 2009.10.16
- CHT: 2010. 08.01
- HFT : 2010.12.01
- Initial Fuel Loading : 2011.04.01
- Shin Wolsong #1 commercial operation : 2011.10.31
- Shin Wolsong #2 commercial operation : 2012.10.31

6. COMMISSIONING TEAM

KHNP is responsible for commissioning of NPP projects. Staffing plans are initiated from 6 to 12 months prior to establishing the commissioning organization. These plans assist in preparing for initial recruitment.

The commissioning office will be established from 48 months prior to commercial operation. Also the experienced employees will be transferred from existing plants and disposing initial recruitments. A source for initial recruitment is employed persons through an entrance examination. This team takes charge of Shin Wolsong 1&2 commissioning.



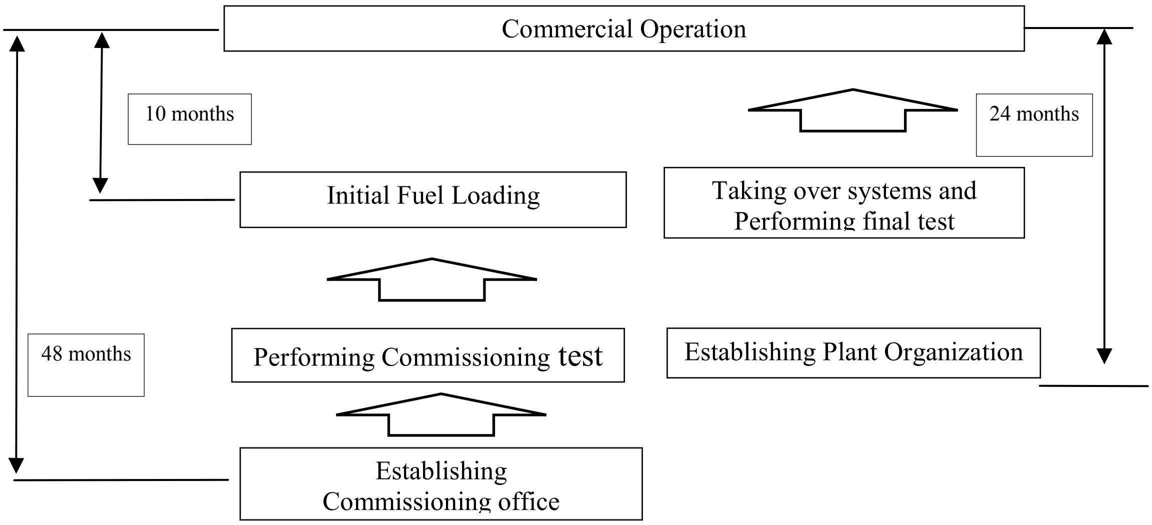
There is one commissioning manager and five sections; about one hundred eighty employees in total. NSSS, BOP and Auxiliary Sections will take charge of turn-over and commissioning of systems. The operations section is responsible for the training for the commissioning team including operator training.

Classification	**Time**	**Staffs**	**Organization**
Establishing Commissioning office	48 months from before commercial operation	55 persons	1 section 5 subsections
Reinforcing Commissioning office	36 months from before commercial operation	180 persons	5 section 27 subsections
Establishing Plant organization	24 months from before commercial operation	345 persons	11 section 46 subsections

Classification	Time	Staffs	Organization
Reinforcing Plant organization	12 months from before commercial operation	470 persons	12 section 56 subsections

The maximum commissioning staff will be one hundred eighty persons from 36 months before commercial operation and then the plant organization will be established from 24 months prior to commercial operation. Together 470 employees at 56 subsections of 12 sections will staff the plant management and commissioning organizations. It is important to balance the experienced/ inexperienced personnel for commissioning. The ratio of experienced/inexperienced personnel for commissioning is generally 40% to 60%.

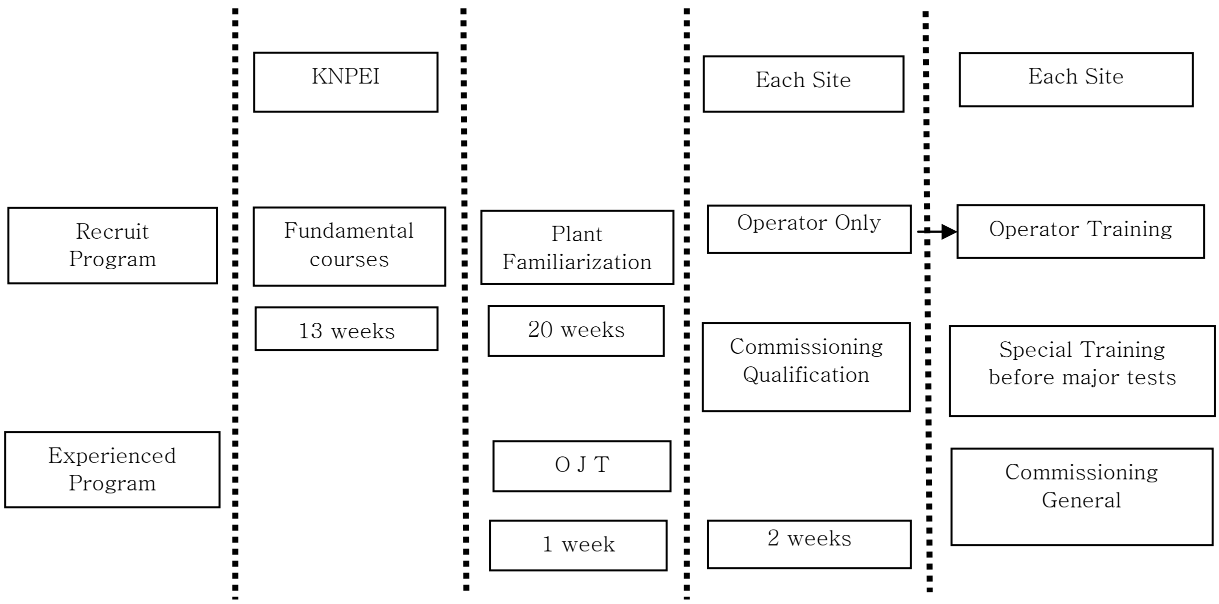
7. COMMISSIONING TRANSFER POINT



After completing commissioning tests, the systems will be turned over from commissioning to plant organizations. At the point of initial fuel loading the plant team will take over responsibility for all systems and perform the final tests including initial reactor criticality and final performance tests.

8. COMMISSIONING STAFF TRAINING

A commissioning training plan will be completed as soon as the commissioning office is established.



* KNPEI : KHNP Nuclear Power Education Institute

There are two different training programmes to educate the employees for commissioning. One is a recruit programme and the other is for experienced staff. The recruit programme for initial recruits is a 13 week fundamental course in KHNP Nuclear Power Education Institute, 20 weeks for a plant familiarization course onsite and 2 weeks for a commissioning qualification course.

The programme for experienced employees covers 1 week for on-the job-training and a 2 week commissioning qualification course onsite.

While the fundamental course performed in KNPEI provides generic and theoretical training for all new employees, the plant familiarization course consists of on-the job training in order to familiarize employees with the plant, its physical layout, the basis of plant operation and various procedures. After completing the commissioning qualification course, based on their assigned tasks/position individuals are assigned job-specific training such as operator training before participating in major tests.

The recruitment programme includes 3 weeks for orientation and 7 weeks for nuclear theory fundamentals, 3 weeks for the plant system fundamentals and 7 weeks for 1st plant familiarization onsite, 7 weeks for system details in the training center at each site, and finally 6 weeks for the 2nd plant familiarization onsite.

No.	Course	Location	Duration
1	Orientation	KNPEI	3wks
2	Nuclear Theory Fundamentals	KNPEI	7wks
3	Nuclear Plant System Fundamentals	KNPEI	3wks
4	Plant Familiarization (OJT-Ⅰ)	Site	7wks

No.	Course	Location	Duration
5	System Details (Each Reactor Type)	Training Center	7wks
6	Plant Familiarization (OJT-Ⅱ)	Site	6wks

Totally 33 weeks are required to cover all the fundamental courses.

9. OPERATOR TRAINING

The operator training course consists of 6 weeks for operator local training and 4 weeks for FCO, OM training onsite, Then MCR operators will be trained for 10 weeks at a training center. Also RO/SRO license training prepares MCR operators to meet license requirements prior to the start of commercial operation, including simulator at the training center for 7 weeks.

No.	Course	Location	Duration
1	Operator Local Training	Site	6 weeks
2	FCO and OM Training	Site	4 weeks
3	MCR Operator	Training Center	10 weeks
4	RO/SRO License	Training Center	7 weeks
5	Simulator	Training Center	9 weeks

MCR operators will be trained for 9 weeks in a training center in order to familiarize them with MCR panel configurations and practical training related to system tests and operation before initial fuel loading. This will be followed by 3 weeks simulator retraining every 4 months.

KHNP has six simulators based on reactor design differences. MCR operators of Shin Wolsong will have to be trained in UCN#3 or YGN#3.

Location		Reference Plant	Operation Date	Manufacturer	Application	Remarks
KOR T/C	#1	KOR #2	Nov. '98	Samsung	KOR #1&2	PWR 650MWe
	#2	YGN #1	Dec. '86	W/H	KOR #1&2 YGN #1&2	PWR 950MWe
UCN T/C	#1	UCN #1	Jan. '90	CSF	UCN #1&2	PWR 950MWe
	#2	UCN #3	Mar. '02	Samsung	UCN #3,4,5,6	PWR 1000MWe
YGN T/C		YGN #3	Apr. '97	Samsung	YGN #3,4,5,6	PWR 1000MWe
WSN T/C		WSN #2	Dec. '96	CAE	WSN #1,2,3,4	PHWR 700MWe

10. OTHERS

All of maintenance staff will be trained and qualified within KNPEI to perform their assigned tasks, such as mechanical and electrical, I & C maintenance. Some employees will be trained by equipment manufactures, such as Doosan Heavy Industry Company, and others dispatched to overseas training.

Also, some maintenance support personnel participate in commissioning to take charge of the maintenance. Korea Plant Service & Engineering supporting Mechanical & Electrical field, or Samchang Company personnel are responsible for I&C maintenance.

11. CONCLUSION

The construction of Shin Wolsong NPP started in 2007. The training of Shin Wolsong NPP personnel will be carried out with good quality and appropriate contents according to a standard training plan. And then, we believe that the Shin Wolsong Project will achieve success.

APPENDIX VI
KHNP STAFFING PLAN OF CONSTRUCTION SITE OFFICE:
ULCHIN 5&6 CONSTRUCTION PROJECT (ROK)

1. INTRODUCTION

KHNP, as an owner/operator organization, is responsible for all project activities including design, procurement, construction, and commissioning, for Korea's nuclear power plant (NPP) construction projects. Four separate functional offices of KHNP are set up to complete the construction management work. These offices are (1) home office, (2) field construction office, (3) field quality assurance office, and (4) field startup/commissioning office.

This paper presents a staffing plan for the field construction office starting initial project implementation to final turnover to operations stages. It is recognized that the plan may not be applicable to other utility situations in terms of project management of site activity depending upon how the overall project contract is structured.

2. GENERAL DISCUSSION

The proposed staffing plan is for an NPP construction project with two PWR units of 1,000 MWe capacity.

The field construction office has overall responsibility for all construction activities that are needed during the construction phase, up to construction completion and construction testing. One of the field construction office's tasks is to oversee and coordinate all construction and contractor's activities at the site by managing 20 different construction packages (e.g., civil, architecture, mechanical, piping, electrical etc.). Its services also provide general direction and coordination of construction activities to comply with the project schedule, coordinating contractor schedules and utilization of equipment and personnel, and maintaining proper standards of safety, security, fire prevention and housekeeping.

3. CONSTRUCTION PHASE

The entire construction project is divided into ten project phases to provide better management control and appropriate links to the ongoing operations of the performing organization. Each project phase normally includes a set of defined work products designed to establish the desired level of management control. The conclusion of a project phase is marked by a review of both key deliverables and project performance in order to determine if the project should continue into its next phase and detect and correct errors cost effectively.

The ten construction phases are defined in the following table:

Phase	Duration	Description	Staffing Plan
I	D-16 ~ D+3 (19 months)	Project Conception (National Electricity Supply Plan → Detailed Project Plan)	10 persons
II	D+4 ~ D+25 (25 months)	Project Preparation (Detailed Project Plan → Finalizing Major Contracts)	38 persons

Phase	Duration	Description	Staffing Plan
III	D+26 ~ D+45) (20 months)	Construction Preparation (Finalizing Major Contracts → Start of Site Preparation)	70 persons
IV	D+46 ~ D+57 (12 months)	Site Preparation (Start of Site Preparation → Excavation)	114 persons
V	D+58 ~ D+65 (8 months)	Foundation Works (Excavation → First Concrete Placement)	156 persons
VI	D+66 ~ D+85 (20 months)	Building Structures (First Concrete Placement → Reactor Vessel Setting)	214 persons
VII	D+86 ~ D+112 (25 months)	Mechanical/Electrical Construction (Reactor Vessel Setting → Fuel Loading)	227 persons
VIII	D+113 ~ D+120 (8 months)	Startup/Commissioning (Fuel Loading → First Unit Commissioning)	185 persons
IX	D+121 ~ D+132 (12 months)	Second Unit Commissioning (First Unit Commissioning → Second Unit Commissioning)	117 persons
X	D+132 ~ D+138 (6 months)	Construction Close-out (Second Unit Commissioning → Close-out)	50 persons

4. STAFFING MANAGEMENT PLAN

The staffing management plan describes when and how human resources will be brought onto and taken off the project team, which is broadly framed, based on the needs of the project experienced in the previous project performances. The staffing sizes for each phase are determined based on the activities that are on the critical path of project schedule where manpower level is critical. Manpower on other activities may be shifted to keep your level close to the same total crew sizes.

Initial staffing will be filled with experienced personnel from existing plant in key position and later, entry level positions staffed with young people who are recent graduates of universities and technical schools. This approach provides an effective means to transfer the operating organization’s culture and work management methods to the new plant. Particular attention should also be paid to how project team members (individuals or groups) will be released when they are no longer needed on the project.

Although the chronological man loading of the field organization personnel for accomplishing the Phase I through Phase X is shown in the table presented above, the detailed staffing plan is described in the following paragraphs:

Phase I: Project conception (national electricity supply plan → detailed project plan)

— Field construction support organization: Site evaluation and accounting function of compensating for land acquisition
— The disciplines of staffing are composed of mechanical (1), electrical (1), civil (1), architect (1), and administration (1).
— A field construction office is established at the time when a detailed project plan is finalized.

— The Phase I tasks includes public relations, site environmental evaluation, basic design, planning of relocation, land acquisition, etc.

Phase II: Project preparation (detailed project plan → finalizing major contracts)

- — Assignment of field construction manager and supporting managers (project control, civil engineering, administration)
- — The staffing consists of mechanical/electrical (10), civil/architect (16), and administration (12).
- — The field construction office assumes full responsibility of handling public relations with local residence and governments.
- — The typical tasks during Phase II are obtaining required licenses from local governments, planning and preparation for civil works, continuing tasks of public relations, land acquisition, and relocation.

Phase III: Construction preparation (finalizing major contracts → start of site preparation)

- — The site organization expands to consist of four departments (project control, civil engineering, mechanical/electrical engineering, and administration)
- — The staffing increases to a total of 70 persons, which includes mechanical/electrical (27), civil/architect (27), communication (2), and administration (14).
- — During this phase the contract and information management sections are established to handle increased contractor's work.
- — Added tasks in this phase are preparation of written procedures for construction management and managing site preparation work while performing continuing tasks of public relations, land acquisition, and licensing business.

Phase IV: Site preparation (start of site preparation → excavation)

- — The field organization is structured into three separate departments (quality control, civil engineering, and mechanical/electrical engineering). Each deputy construction manager is assigned to civil and mechanical/electrical engineering.
- — The staffing consists of mechanical/piping/electrical (53), civil/architect (45), communication (1), and administration (15).
- — During this phase the quality control department, planning/scheduling section, and public relations section are established. The civil and architect sections will be separated.
- — The tasks are site preparation, intake and discharge water channel construction, building construction facility and auxiliary power plant, and establishing management systems for scheduling, construction cost control and contractor coordination.

Phase V: Foundation works (excavation → first concrete placement)

- — While the field organization maintains its three department structure during this phase, additional sections are added in order to deal with increased construction management functions.
- — The staffing is composed of mechanical/piping/electrical (77), civil/architect (56), communication (1), and administration (22).
- — During this phase the quality inspection section, constructions support section, contract management section are added to the field organization. The combined mechanical and electrical engineering section is separated into two independent sections in order to manage increased tasks more effectively.
- — Some of the construction activities during this phase include excavation for building foundations, placement of concrete to protect rock formation, continuing tasks of site

preparation for the following unit and intake and discharge water channels, and preparation of construction procedures (SIP, WPP/QCI, etc.)

Phase VI: Building structures (First concrete placement → reactor vessel setting)

— The field design section is added to handle design discrepancies and field routing of piping and wiring.
— The field construction staffing consists of mechanical/piping/electric/I&C (116), civil/architect (65), communication (3), and administration (30).
— During this phase the mechanical and piping engineering section is separated as an independent group to handle increased construction tasks. The electrical engineering section is reinforced with additional I&C engineers.
— The tasks includes underground electrical and piping construction, start of administration building, and continuing tasks of excavation, foundation for building structures, and preparing construction procedures.

Phase VII: Mechanical/electrical construction (reactor vessel setting → fuel loading)

— The staffing of civil engineering and architect section is reduced as civil construction activities diminish.
— The staffing consists of mechanical/piping/electrical/I&C (139), civil/architect (59), communication (4), and administration (25).
— Since the volume of I&C tasks increase, the I&C engineering group is separated from the electrical engineering section.
— Installation of NSSS equipment, installation of mechanical and electrical components, completion of structural buildings and intake/discharge channels, turn-over of first unit systems and areas to start-up/operations and completion of first unit construction

Phase VIII: Start-up/commissioning (fuel loading → first unit commissioning)

— The size of the field construction organization is reduced as the first unit construction is close to commissioning.
— The staffing consists of mechanical/piping/electrical/I&C (116), civil/architect (45), communication (3), and administration (21).
— The field design section closes as field design work diminishes.
— Close out of first unit construction, preparing for first unit commissioning, turn-over of second unit systems and areas, completion of second unit mechanical and electrical construction.

Phase IX: Second unit commissioning (first unit commissioning → second unit commissioning)

— While reduction in the field construction organization continues during this phase, civil engineering and architect sections are consolidated into a single organization.
— The staffing consists of mechanical/piping/electrical (71), civil/architect (26), communication (3), and administration (17).
— During this phase the civil engineering and architect sections are combined into a single section. Furthermore, the planning/scheduling section, the quality inspection section, and I&C engineering section are closed.
— Some of major tasks during the phase are commissioning of the first unit, regional turn-over for the second unit, and settlement of accounts.

Phase X: Construction close-out (second unit commissioning and construction close-out)

- — The field organization is downsized to a construction management section, a mechanical/electrical engineering section, and a civil/architect section.
- — The staffing consists of mechanical/piping/electrical (32), civil/architect (11), and administration (7).
- — The major tasks are finalizing construction contracts and preparing a lesson-learned report.

5. CONCLUSION

KHNP developed a staffing plan for a construction site office that manages construction activities at the site. This staffing plan is primarily intended for use by the KHNP project management that is considering the initial implementation of nuclear power construction projects. Although this plan may not be directly applicable to other nuclear industry organizations since project contract structures may be different one another, it could be used as a reference for field construction office staffing requirements.

APPENDIX VII
COOPERATION BETWEEN KALININ NPP AND UNIVERSITIES (RUSSIAN FEDERATION)

The region of Kalinin NPP location is sparsely populated, does not have enough staff and educational institutions capable of training the number of qualified staff needed for the nuclear industry in the region. The peculiarity of the Kalinin NPP location is its relative nearness and at the same time remoteness from big industrial cities (central region, Moscow, north-west, St.-Petersburg), which causes a permanent outflow of qualified staff into these regions. Due to this fact, Kalinin management has to solve the tasks of attracting high school graduates to the region and attracting university graduates from other regions.

Solving these tasks is done through the implementation of specific measures, the most important of which are:

- Developing a positive image of the nuclear plant among the population.
- Developing motivation among the students of regional schools to seek training and education in the specialties connected with nuclear industry.
- Organization and implementation of pre-university training for schoolchildren to direct them towards entering the universities that train specialists for the nuclear industry.
- Providing benefits and compensations for fresh specialists, university graduates and young nuclear workers to attract them to the nuclear power plant.

To solve these tasks, in addition to the main departments of the Kalinin NPP there are the following additional ones:

- *Information department*, informing the local population about production activities, achievements and problems at the NPP via regional and corporate mass media, in particular, through a weekly plant newspaper, plant radio on the federal channel, and town and local TV channels.
- *Public Relations Center*, arranging and providing meetings of the public with plant managers and specialists, excursions for schoolchildren and representatives of public organizations. Together with the town educational center it arranges subject-matter competitions and contests for school graduates. In the Center there is a functioning Museum of the Kalinin NPP.
- *The Center for work with personnel and population* implementing the programmes aimed at improvement of public activity and development of cultural and creative potential of NPP workers, their families and the local population.
- *A large sports facility* that provides the opportunity to conduct corporate, regional sport and recreation arrangements as well as arrangements on professional rehabilitation of plant personnel.

To attract and retain workers for the nuclear plant they are provided with special benefits and compensations. In the plant collective bargaining agreement there are regulations on the status of fresh specialists and benefits and compensations provided to them. Fresh specialists, university graduates from other regions, get compensation of the expenses paid for their move to the working place at the NPP, and get accommodations in the hostel. In spite of an existing outflow of qualified staff from the region, there are not enough apartments in the secondary market in the town to accommodate the needs of the personnel recruited to nuclear plant during unit 3 commissioning. Therefore nuclear plant management promotes the development of corporate system of mortgage lending. To solve specific social problems, fresh workers are provided with interest-free loans.

Among Russian technical universities there are only a few having a license to train specialists in nuclear facilities operation. According to the decision of the Russian Ministry on Nuclear Energy (Minatom) and the Ministry of Education, Obninsk University is considered to be the basic university on personnel training for Minatom enterprises. In addition, Kalinin NPP maintains permanent cooperation with the Moscow Physical Engineering University, Moscow Power Engineering University, St. Petersburg Technical University, Moscow Chemical Technological University, Tomsk Polytechnic University and some other universities. Cooperating with these universities includes:

— Joint discussions on the contents of training plans and programmes for the specialties connected to nuclear plant operation,
— Arranging and conducting training for students at plant working places as well as in the Training Center on safety requirements during NPP operation (industrial, radiation, fire safety) before training at the working places,
— Based on industrial tasks, defining long-term and annual demand for university graduates at the plant.

The plant personnel department calculates the summary demand and selects graduates.

Ivanovo Power Engineering University was established as the basic one for Kalinin NPP. According to a mutual decision between the plant and university management. A branch of the physical engineering department of Ivanovo University is organized at the Kalinin NPP. In the framework of branch activity, additional programmes and training materials for the students have been developed. During the 8^{th} semester (the end of the 4^{th} year) plant specialists provide, directly at the plant, classroom training as well as workshops and laboratory sessions for the students of Ivanovo University. Kalinin NPP handed over to Ivanovo University a full-scope simulator developed before upgrading Kalinin 3 automated process control system (APCS) according to the standard design of nuclear unit with VVER-1000 reactor type, as well as Kursograph software developed by the specialists of Kalinin Training Center and applied for development of computer-based training courses for studying nuclear plant systems, components and processes. Ivanovo specialists handed over to Kalinin NPP Dopusk software designed to study and check the requirements of safety standards.

In 1986, the technical school for training the workers for the nuclear industry was founded in the area of the Kalinin NPP. Plant management together with technical school management provide for:

— long-term and annual estimation of demand in school graduates based on jobs and necessary amount of workers (considering demand of NPP, contractors and region itself),
— agreement of programmes and training plans (evaluation, reviews),
— organization and arrangement of laboratory training,
— participation of NPP specialists in training in specific specialties (welders, fitters, electric workers),
— development of technical school training facilities,
— application of existing training facilities of the technical school for plant personnel training,

— development and application of electric equipment simulator to train plant personnel and students,
— participation of NPP specialists in state qualification committees.

Through the initiative of NPP management and Obninsk University of Nuclear Engineering, a specialized secondary school with physical and mathematical basis was founded in the town. In the technical school there are permanent courses helping the school graduates to enter technical universities.

APPENDIX VIII
EXPERIENCE GAINED FROM EARLIER PLANTS IN COMMISSIONING TRAINING AND HUMAN RESOURCE FOR MOCHOVCE NPP (SLOVAKIA)

1. INTRODUCTION

There are two operating NPPs in the Slovak Republic. The older one is the Bohunice NPP with 4 Units and the newer one is the Mochovce NPP with 2 Units. Bohunice Units 1&2 were commissioned in 1978-1980, Units 3&4 were commissioned in 1983-1985 and Mochovce Units 1&2 were commissioned in 1998-2000. At the time described in this appendix the owner of the both NPPs was the state-owned joint stock company Slovenske elektrarne, a.s. (Slovak Electric, Inc.).

An important role for Slovak NPPs in the areas of NPP commissioning and NPP personnel training has been played by VUJE Inc., especially its two divisions:

— VUJE Commissioning Group
— VUJE Training Centre.

In terms of training for commissioning this appendix is an example of :

— **Expansion of existing NPP fleet.**

  Mochovce Units 1&2 were of the same VVER-440/213 type as the Bohunice Units 3&4, which have been operated since 1983-1985. It was an advantage for the Mochovce NPP because many of experienced and trained people from the Bohunice NPP could be recruited for key functions and for other positions at the Mochovce NPP. Another advantage was that new inexperienced Mochovce employees could be trained at the Bohunice NPP during the Mochovce NPP construction.

— **Significant design change during NPP construction.**

  The original project of the Mochovce NPP was changed during construction. In 1991, the management of the Mochovce NPP decided that the original Process Control System would be replaced by the new one from Siemens AG. After this Project change, the new Control Room Simulator, new training programmes and new training materials had to be developed for training of personnel for commissioning of the Mochovce NPP. All the Mochovce personnel, that had been trained by Bohunice programmes in 1982-1993, had to be additionally retrained by Mochovce training programmes.

— **Project of delayed NPP construction.**

  The construction of the Mochovce NPP was delayed for several years. The Mochovce NPP construction started in November 1982 and it generally met its schedule until 1989. After the political changes in Czechoslovakia in 1989 (the velvet revolution), some problems around the Mochovce NPP construction occurred (additional safety questions, environmental aspects and financial problems, mainly). In 1993, these problems caused a complete stoppage of Mochovce NPP construction. The construction continued again in 1996 and it was successfully completed at Unit 1 in 1998 and at Unit 2 in 2000. In terms of personnel training for Mochovce commissioning, the project delay had a positive impact, because there was extra time for education and training of personnel for commissioning of the Mochovce NPP.

Key milestones

Construction start:	November 1982
NPP Project change:	1991
Construction stopped:	1993
Simulator delivery:	July 1995
Construction resumption:	August 1996
Fuel loading at Unit 1:	April 1998
	Operation start of Unit 1: October 1998

2. STAFFING PLAN FOR COMMISSIONING

The initial recruitment and selection of Mochovce NPP personnel was prepared from 5 to 7 years prior to fuel loading (PTFL) at Unit 1. Three years PTFL, the staffing plan for commissioning was updated. The plan was finalized 14 months PTFL. The operating organization had the lead responsibility for preparing the staffing plan.

The staffing plan for the Mochovce NPP included an analysis of the required number of people in each of the functional areas (job positions) needed for commissioning and the levels of qualification and experience needed for each position. The plan included a specification of 24 key functions with requirements to hire experienced personnel from the Bohunice NPP or the Dukovany NPP (Czech Republic). This target was evaluated later and it was met in 95 % of the cases. Experienced personnel from Bohunice NPP were also hired for other positions at Mochovce NPP. For the NPP Commissioning Division the ratio of experienced/inexperienced personnel was approximately 90/10 %. At the NPP Operational Division the ratio was approximately 40/60. As the construction of the Mochovce NPP was postponed for several years, the inexperienced personnel had enough opportunities to become experienced, e.g., they went to work at the Bohunice NPP or they were involved in Mochovce NPP commissioning work. The Mochovce NPP personnel also carried out mostof Mochovce NPP commissioning activities (almost 90 %).

The active part of Mochovce NPP commissioning was carried out by the VUJE Commissioning Group (VCG). The VCG had commissioned Bohunice and Dukovany NPPs, so there were about 80 experienced personnel in the VCG. The VCG also hired about 20 young specialists during the last 3 years PTFL at Mochovce Unit 1. The ratio of experienced/inexperienced personnel was 80/20 %.

3. COMMISSIONING TRAINING PLAN

During the early stages of Mochovce NPP construction (1982-1993), operating personnel were trained according to training programmes prepared for Units 3&4 of the Bohunice NPP. After the project of the Process Control System was changed, new training programmes and materials for the Mochovce NPP had to be prepared. In January 1993, the partial quality assurance plan for plant operation was prepared and issued at the Mochovce NPP. In this plan, the new approach to the training of Mochovce NPP personnel was presented. The plan included Instruction QA-03-02 “Personnel Training”, which defined:

— Classification of employees into 6 training categories (Table 1) and 33 profession groups
— Professional, medical and psychological criteria for assessment of competence for specific job position

— Criteria for trainers and instructors, training facilities and requirements for training programmes
— System of training and education
— Requirements for timely preparedness of personnel according to the schedule of commissioning activities
— Criteria for assessment of training activities and application of feedback.

TABLE 1. CLASSIFICATION OF NPP PERSONNEL INTO TRAINING CATEGORIES

Cat.	Personnel	Job Positions
I	Licensed personnel	Personnel with direct impact on nuclear safety: shift supervisor, unit shift supervisor, reactor operator, turbine operator, reactor physicist, training instructors for Category I, personnel for NPP commissioning
II	Technical and economical personnel and foremen	Personnel with university and high school degree who carry out jobs in operating, technical and maintenance sections of NPP (managers, personnel of operational, technical, maintenance sections, foremen, instructors)
III	Shift and other operating personnel	Personnel who perform manipulations on technological equipment except foremen (groups: primary plant, secondary plant, I&C, electrical systems, chemistry, health physics, rad-waste management)
IV	Maintenance personnel	Personnel who perform maintenance of technological equipment (groups: mechanical maintenance, electrical maintenance, I&C maintenance, maintenance of equipment used in health physics)
V	Plant decommissioning personnel	Health physics & dosimetry, decontamination, operation & maintenance, chemistry, rad-waste treatment, spent fuel management, rad-waste repository, environment, electrical systems + I&C, decommissioning, rad-waste transport
VI	Other personnel	

In the commissioning training plan, SAT principles were used and implemented including effective feedback. The commissioning training plan addressed all aspects of commissioning required for individual job positions. Great attention was paid to topics such as commissioning organization, commissioning methods and techniques, nuclear safety, safety culture, quality assurance, environmental protection, and waste management. Training on the design characteristics of plant systems and practical training on plant systems was of great importance, too. Each profession group had its individual training plan and its own training content.

Initial training included theoretical training. Preparation and examination for obtaining a certificate or license exam was carried out at the VUJE Training Centre. The rest of initial training, such as simulator training, on-site training, on-the-job training and exam for obtaining authorisation was the responsibility of the Mochovce NPP. Licenses for the Category I personnel were issued by the Nuclear Regulatory Authority of the Slovak Republic (NRA SR) based on the results of the exams.

After NPP basic training completion, shift operating personnel participated in “shift personnel training days” (the training was carried out in parallel with their job). Staff training and working meetings were also carried out before the start of individual commissioning stages to teach the personnel about actual working programmes and other commissioning activities.

The commissioning training plan of the operating organization and also at the VUJE Training Centre had to be approved by the NRA SR. The completion of commissioning training was an obligatory qualification requirement for commissioning personnel. The operating organization did not issue “An authorisation for function execution” to any worker until the completion of required training courses and all working or qualification requirements. A worker with “An authorisation for function execution” was allowed to carry out assigned job individually and without direct supervision. The necessary level of qualification and experience for each position in the commissioning organization was specified and strictly checked. Any exception could be used only in accordance with the NRA SR requirements and conditions, but they were used very rarely.

The duration of commissioning training programmes for the control room personnel (Category I: reactor operator, turbine operator, reactor physicist, unit shift supervisor, shift supervisor, scientific shift supervisor) was 14 months. For technical support personnel (Category II) it was 20.5 weeks and for maintenance personnel (Category IV) it was 13 weeks. Duration of initial training phases is shown in Table 2.

TABLE 2. DURATION OF INITIAL TRAINING OF MOCHOVCE NPP PERSONNEL IN WEEKS

Phase of Initial Training	**Training Category**			
	I	**II**	**III**	**IV**
Theoretical training	22	13	6	6
On-site training	18	6	6	6
Simulator training	6	-	-	-
Exam for certificate	2	1.5	1	1
On-the-job training	4	jd	jd	jd
Exam for license issued by NRA SR	4	-	-	-
Exam for authorisation issued by NPP	ad	ad	ad	ad

jd - duration depended on the type of job

ad - duration depended on the Mochovce NPP administration

Commissioning training for the Mochovce NPP commissioning was completed 1 month PTFL at Unit 1. In total, 1029 NPP employees had completed the training. The 42 control room personnel obtained the license for their work 1 month PTFL.

The operating organization had to document the preparedness of personnel for commissioning of Unit 1 to the NRA SR. Based on that, the NRA SR issued the license to start the stages of commissioning at shown in Table 3.

TABLE 3. ISSUING OF THE LICENSES BY NRA SR BEFORE START OF COMMISSIONING STAGES AT UNIT 1

Licence for Commissioning Stage	Start of Stage	License issued
Initial fuel loading	27 April 1998	24 April 1998
Power start-up tests	24 June 1998	22 May 1998
Trial operation	06 October 1998	20 August 1998

4. TRAINING MATERIALS FOR COMMISSIONING

During the early stages of Mochovce NPP construction, operating personnel were trained at the VUJE Training Centre according to training materials prepared originally for the Bohunice Units 3&4. On-site training and on-the-job training were also carried out at Bohunice Units 3&4. After the change of Process Control System project, all these employees had to be additionally retrained for the Mochovce NPP (1997–1998). Since September 1993, the Mochovce NPP personnel were trained at the VUJE Training Centre according to the textbooks prepared exclusively for the Mochovce NPP. SAT principles started to be used in personnel training. They continuously became the main principles in process of training and preparation of personnel for VUJE Training Centre and the operating organization (Mochovce NPP).

All training materials had to be prepared in advance, approximately 2 months before the training start. The following organizations were responsible for development of training materials:

— VUJE Training Centre, Trnava
— System and component suppliers
— The operating organization (Mochovce NPP).

The training programmes were developed by the VUJE Training Centre. They were approved in 1994 (4 years PTFL) and their next revisions were approved gradually till 1997 (i.e. one year PTFL). The actual training programmes for individual commissioning stages were prepared by the operating organization 1 month in advance. The licensing of training programmes took only about 1 month because the contents of the programmes were consulted with the NRA SR in advance.

5. CONTROL ROOM SIMULATOR TRAINING

The full-scope control room simulator for the Mochovce NPP was not a part of the original Mochovce NPP project. As the original Mochovce NPP project was the same as the Bohunice Units 3&4 project, it was planned, that the Mochovce NPP personnel would use the Bohunice Units 3&4 simulator in the VUJE Training Centre.

Immediately after the decision to replace the Process Control System at Mochovce Units 1&2 in 1991 (approximately 7 years PTFL), the management of the Mochovce NPP started the process of supplier selection, ordering, construction and licensing of new full-scope simulator for control room personnel training. Political changes after 1989 allowed free transfer of technology and know-how to central Europe. State of the art solutions from all around the world were considered before the decision to build the simulator was made. Delivery of the

Mochovce NPP simulator was an example of international cooperation of S3 Technologies (United States of America), Siemens AG (Germany) and the Mochovce NPP. The full-scope simulator was delivered in 1995. The simulator trial operation started 2 years and 8 months PTFL. During the trial operation, the simulator was used for verification of operating instructions, test procedures and preparation of training programmes. These activities were carried out in collaboration with future control room personnel, which helped them to prepare for their jobs. Simulator tests, training of simulator instructors and preparation of detailed documentation was also carried out. The result of this process was the license for simulator training issued by the NRA SR on 7 April 1997.

Approximately one year PTFL, the simulator training of control room personnel for the Mochovce NPP started. The simulator training was provided for the following positions: reactor operator, turbine operator, unit shift supervisor, shift supervisor, reactor physicist, scientific shift supervisor (VUJE employees). In total, 42 control room operating personnel were trained PTFL at Unit 1. According to the training programme, new control room shift members started to work as turbine operators, after gaining the required experience and qualification they could work as reactor operators and later as unit shift supervisors. The duration of simulator training was 6 weeks for initial training for Category I positions. In case of position change, e.g. the change from turbine operator to reactor operator or from reactor operator to unit shift supervisor etc., additional 2-weeks of simulator training had to be completed.

The simulator was in operation 2 shifts per day (2*8=16 hours of simulator operation) during the training PTFL at Unit 1. The first shift was from 0600–1400 and the second one from 1400–2200. During the first hour (from 0600-0700) simulator preparation and briefing were carried out by an instructor, then the personnel training consisting of demonstration and practice was carried out from 0700–1200 and from 1200–1400 the training evaluation and debriefing were carried out in other class room (out of the simulator room). The net training time at simulator was 2*4=8 hours per day.

6. TRAINING ORGANIZATION FOR COMMISSIONING

The VUJE Training Centre as a contractor provided the training for the Mochovce NPP. At that time, the VUJE Training Centre had approx. 60 employees. The licensed lecturers were recruited at least 5 years PTFL. One of the lecturers was formerly a reactor operator at the Bohunice NPP.

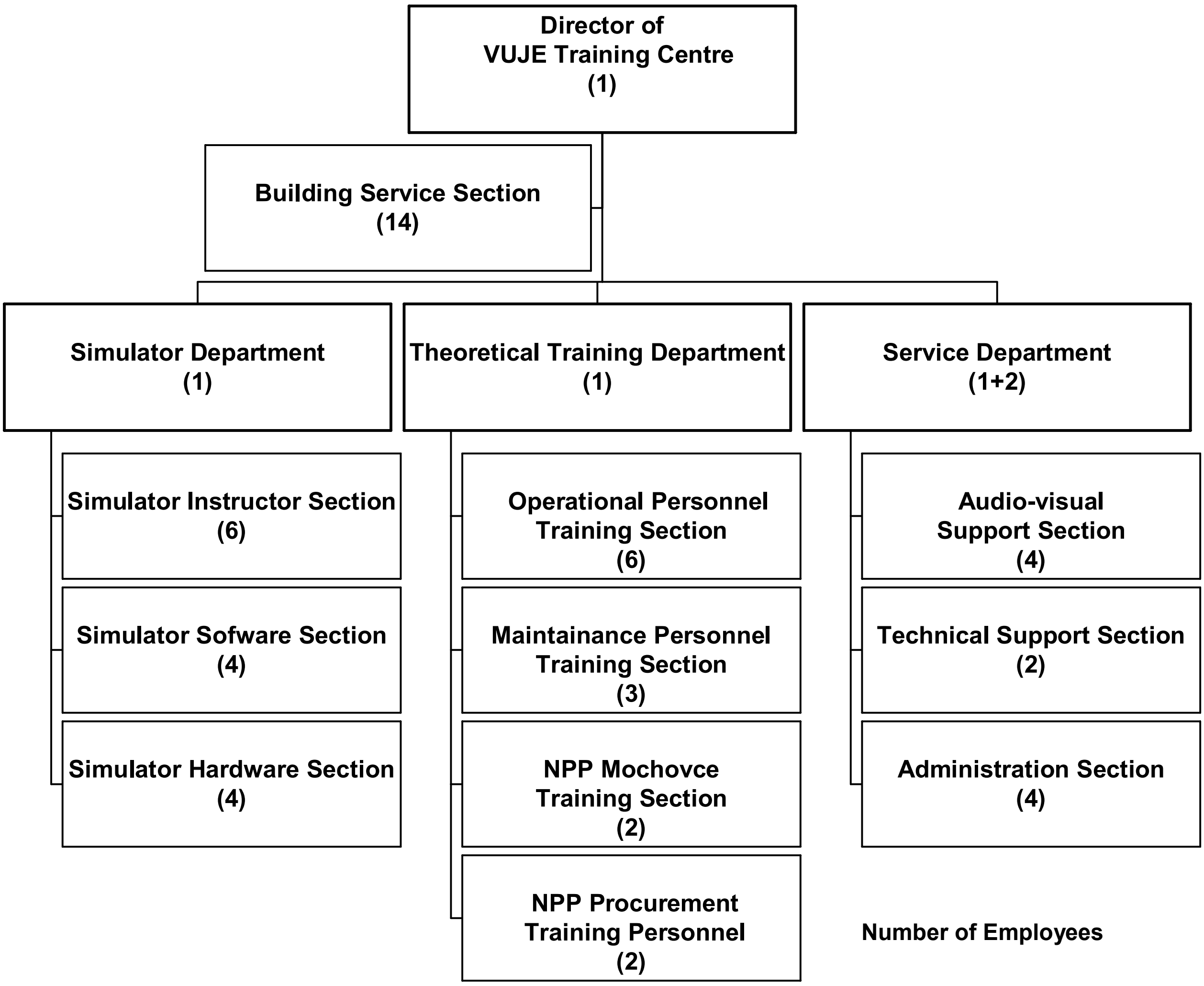


Figure 1. The organization chart for the VUJE Training Centre.

If any significant incidents occurred during the commissioning of Unit 1 they were incorporated into training programmes and materials for training of personnel for commissioning of Unit 2. Experience gained during the commissioning was reported to training organization. As the training of personnel was carried out at the site of the Mochovce NPP, the information transfer was very quick.

7. SYSTEM ENGINEERS

The system engineers were responsible for a system, structure or component. These workers were involved in providing training for NPP commissioning and operation. They were also used as lecturers at the VUJE Training Centre and at NPP Mochovce.

8. MAINTENANCE TRAINING DURING COMMISSIONING

The operating personnel (including I&C specialists) were actively involved in all commissioning activities. The maintenance personnel carried out also so-called "repassed works" of all NPP equipment before the NPP commissioning. Before the NPP Mochovce commissioning started, the maintenance personnel had been actively involved in the maintenance of the Bohunice Units during their outages and at Slovak fossil power plants, too.

9. CONCLUSION

Well-trained personnel are one of the most important aspects of safe NPP operation. The fact that both Mochovce NPP Units have been operated safely since their commissioning in 1998–2000, indicates that the training of Mochovce NPP personnel was carried out with good quality and appropriate content.

APPENDIX IX
COMMISSIONING TRAINING ISSUES ASSOCIATED WITH NEW NUCLEAR PLANT STARTS: A FUTURE VIEW FROM A HISTORICAL PERSPECTIVE (UNITED STATES OF AMERICA)

1. BACKGROUND

During the commissioning (startup) of the present fleet of American nuclear plants there were shortages of experienced construction test and startup test engineers. Given the US regulatory requirements associated with new plant starts (i.e., Chapter 10 US Code of Federal Regulations Part 52), there will be even greater knowledge and performance demands on the staff assigned to these new plants than those in the 1970s and 80s. Success in future startups, resulting in plants with high sustained capacity factors, means that systematic efforts to avoid a similar shortage of qualified startup personnel must be undertaken today. This Appendix describes some historical aspects of US nuclear plant construction in an effort to identify approaches to improved performance of plant staff as they construct, start and operate the new generation of reactor plants.

The need for a new generation of highly trained construction and startup testing staff finds its roots in many places. The expectations of the financial community, nuclear industry (both domestic and international), regulatory bodies, governmental bodies, and the public are far different from when the existing fleet of commercial American nuclear plants was constructed and started. The next wave of light water commercial nuclear plants will be constructed and brought on line in a significantly more rigorous atmosphere. Construction and startup of new plants must be predictably short and essentially trouble-free. Staff must be sufficiently trained to recognize and resolve problems before they occur as opposed to waiting for problems to emerge.

Construction Testing and Startup Testing are crucial parts of construction and initial operation of a plant. In the previous generation of reactors, these activities were performed with Construction Test and Startup Test Engineers. The tests they performed verified that the plant's systems, structures, and components had been properly constructed and prepared, and were operating as designed. These terms (construction test engineer and startup test engineer) have different meanings in different countries but essentially the commissioning functions and allied responsibilities are implied as a part of the follow-on discussions in this Appendix.

2. A BRIEF HISTORY OF STARTUP ENGINEERING

In the late 1960's the early American plants were turnkey where a reactor vendor partnered with an Architect/Engineer and built a few of the early plants for a fixed price. The turnkey startups were orchestrated largely by experienced personnel from the reactor vendors who directed the relatively inexperienced utility engineers and operators, A/Es, and other vendors. At the time, some of the best and brightest worked for the reactor vendors.

While successful in launching commercial nuclear power, the turnkey approach lost money. By the middle to late 1970's the orchestration was shifting to the utilities and was essentially complete by the Three Mile Island accident in 1979.

The demand for startup engineers was so great and supply so limited that engineers left the Navy, A/Es, and vendors to become highly paid independent contractors. Most honed their skills on the job over several plants and many years. In time these contractors became increasingly valued for their experience and knowledge of what succeeded or failed at earlier plants. They coordinated testing requirements, wrote and conducted test procedures, analyzed test results, completed documentation, and interfaced with the utility's staff, the NRC, the reactor and turbine vendors, and construction personnel. With successive startups, their increasing knowledge and experience translated to ever-shorter and more successful test programmes and because they did not have a corporate overhead, they cost less than personnel from vendors and A/Es. They were successful because they worked hard, concentrated knowledge, and provided greater value than the competition.

The peak number of startups was reached in the mid 1980's and the construction and startup engineers joined utilities, regulators, and vendors or A/Es, where they are not likely to remain because of pensions and other retirement benefits. Many more have left the industry for retirement or careers elsewhere. The vast majority of startup engineers joined utilities in the middle part of their careers, after there were no more startups. Even though they had worked for utilities at high levels, they had been outside the utility's career ladder. As a result, by the time they joined a utility, the career ladder was already filled, thus many entered at relatively low positions.

The upcoming period of construction and startup testing, beginning in about 2010, will have access to few experienced startup engineers. If several plants are started up simultaneously, a shortfall of experienced talent will again occur. The remaining older experienced startup engineers are less likely to work the unlimited hours they did thirty years ago and new Nuclear Regulatory Commission regulations will undoubtedly cap the working hours of all of those involved in the new starts. Limited human resource will provide yet another constraint on the plant construction and startup schedule; a constraint that can only be addressed by highly trained and competent staff.

In contrast to the commercial industry, starting in about 1960, the U.S. Navy had a formal qualification and training programme for startup engineers, when shipyards required startup engineers to be qualified in a three level programme. It was generally observed that ex-Navy personnel were superbly prepared through their training in systems and conduct of operations, particularly following procedures, that made an excellent foundation for the additional first-principled, fundamental understanding that resulted in good startup engineers. Unfortunately, the US Navy is no longer the reservoir that it once was for nuclear personnel of all types.

The most recent US NPP commissioning was the Watts Bar Unit 1 in 1996.

3. SCOPE OF ENGINEERS

The startup staff will conduct testing, quickly and accurately identify problems, lead the effort to accurately determine the cause of the problem, develop workable solutions, and resume safe testing and operation. Although there are specialists, the ideal startup engineer is a generalist with a great depth of understanding in many engineering disciplines including nuclear, controls, mechanical, and electrical engineering, good project management skills, an understanding of the plant's legal environment and its safety analysis, an outstanding work ethic, and the ability to work quickly and cooperatively in a highly controlled and demanding environment.

The startup testing of a nuclear plant involves the entire plant and requires the cooperation and integration of the vendors, utility personnel, and regulators in bringing a power plant's various components, systems, personnel, and supporting infrastructure to safe and efficient operation. It is imperative that the engineers who are involved in construction, startup testing, and initial operation, particularly regulators and utilities, have the necessary skills and technical competence. The following descriptions detail the functions that were performed by these individuals in earlier US plant construction and startup. These same functions must still be performed in any of the new starts, however, the distribution of responsibilities may be somewhat different based on the latest US regulatory requirements (see 10 CFR 52).

Construction Test Engineer - Prepares components and systems for integrated operation in a proceduralized, documented and quality-controlled manner. This includes activities such as:

- Develops test procedures/documentation from manufacturer’s and vendor's guidelines, including acceptance criteria.
- Documents preparation of test procedures, preparation activities, and testing.
- Flushes, hydrostatically tests, aligns, makes initial adjustments, conducts initial operation, and prepares components in mechanical systems for operation.
- Verifies and documents proper installation of components, structures, and systems.
- Checks, calibrates, and initializes instrument and control, and electrical equipment and systems.
- Understands and supports quality control programmes and procedures.
- Quickly and accurately identifies and resolves problems with equipment, installation, and testing in a manner that supports and preserves the quality design of the plant.
- Effectively supervises craftsmen with understanding respect for working agreements.
- Interfaces effectively with the utility's operators, plant engineering and management staff, inspectors and regulators.
- By a questioning attitude and training, anticipates and resolves problems that would unnecessarily delay testing and operation of the plant.
- Understands and is committed to safety.
- Supports scheduling and provides knowledgeable timely input to scheduling activities.
- Provides timely, accurate status reports to startup management.
- Willingly cooperates with all those engaged with plant construction and startup.
- Actively researches vendor manuals and other references to understand the equipment including its operation and limitations before testing or operating the equipment.
- Is aware of the limitations and status of the system that could damage the equipment being tested.
- When possible, uses operating procedures so the procedures are proven by the end of the testing programme and ready for use.
- When practicable, trains utility personnel in operation and maintenance of the equipment and systems.
- Turns over tested systems to startup test organization for hot functional tests.

Startup Test Engineer - Takes the plant from pre-core load hot functional tests through commercial operation in a proceduralized, documented and quality-controlled series of tests (1) from receipt of fuel through commercial operation, (2) at ever-increasing power levels and (3)using expertise in balance of plant, reactor, mechanical, licensing, electrical and I&C engineering. These include specific capabilities and responsibilities as follows:

- Writes test procedures based on requirements and commitments and verifies the procedures are ready by using the plant's simulator, proactively following the experience at other plants, researching INPO and NRC operating experience databases and good practices, and incorporating the latest experience and best practices into the plant being tested.
- Provides leadership and experience in first-time evolutions
- Is familiar with the plant's licensing basis and the impact of testing, test exceptions, and acceptance criteria on the licensing of the plant.
- Interfaces effectively with the utility's operators, plant engineering and management, and inspectors.
- Conducts succinct, accurate, and relevant pre-test briefings and training to operators, engineers, management, and inspectors.
- By a questioning attitude and training, anticipates and resolves problems that would unnecessarily delay testing and operation of the plant.
- Clearly understands the role, responsibilities, boundaries, and limitations of startup test engineers.
- Understands and is committed to safety.
- Supports scheduling and provides knowledgeable timely input to scheduling activities.
- Provides timely, accurate status reports to startup management.
- Willingly cooperates with all those engaged with plant construction and startup.
- Researches vendor manuals and other references, calculates important parameters, and generates reasonably accurate pre-test predictions and guidelines for tests to understand the plant and its operation and limitations before testing.
- Is aware of the limitations and status of the system that could damage the equipment being tested.
- When possible, uses operating procedures so the procedures are proven by the end of the testing programme and ready for use.
- Quickly and accurately identifies and supports efforts to resolve problems with equipment, installation, and testing in a manner that supports and preserves the quality design of the plant.
- Accurately documents testing activities including the startup test report.

4. AN OVERVIEW OF CONSTRUCTION TESTING

Construction Testing is the earliest testing activity on site and occurs while the plant is actively being constructed. Traditionally, construction testing was conducted mainly by the architect-engineer’s and major equipment (i.e. turbine-generator) vendor’s staff with assistance from startup engineers who might be on site and available. The utility’s staff operated the equipment.

Newly assembled piping systems and other components are inspected, filled with water or other operating fluids, flushed and cleaned, and hydrostatically tested. The hydrostatic tests range from small piping systems to the reactor coolant system and the steam generators. The containment is pressurized in a structural integrity test to demonstrate its leak-tightness.

The component’s supporting instrument and electrical systems are inspected, calibrated and energized for the first time, and components are operated individually and then in systems.

The emergency systems are completed and tested, culminating in a test that requires the emergency diesel generators to operate in response to a safety injection signal.

The completed procedures and other documentation, for instance from manufacturers and construction activities, are gathered into turnover packages and stored in document control.

The portion of the plant that receives new fuel will be completed and its security will be established. The new fuel for the first core will have been received by the end of this period.

At the end of the construction period, pre-operational hot functional testing is conducted. The plant's systems are operated together and this integrated operation demonstrates that the completed plant is ready for the nuclear fuel. This point should have largely completed construction activities and experience has shown that the more complete the plant, the smoother and faster the subsequent startup. Traditionally, the utility's and reactor vendor's personnel played a much greater part in this pre-operational hot functional testing, with a greatly diminished presence of the architect-engineer and major equipment vendors.

Limited sets of operating conditions are established during hot functional testing. In pressurized water reactors, for instance, the reactor coolant system is heated to hot standby, the zero power operating temperature, by operating the reactor coolant pumps. The hot standby temperatures and stored heat in the reactor coolant system permit limited testing. The procedures that will be used during plant operation will be used to operate the plant so problems with the procedures can be identified and remedied. Specific tests are conducted using test procedures. The test procedures list initial conditions, expected values, values not to be exceeded, steps to be conducted to collect data, and steps to analyze the data and verify it has met acceptance criteria.

5. AN OVERVIEW OF STARTUP TESTING

The third and final phase, called startup testing, begins after the plant has been cooled from pre-operational hot functional testing.

Traditionally very few personnel from the architect-engineer or major equipment vendors remain on site and the utility and reactor vendor's personnel conduct the balance of testing. Although the transition has not normally caused great problems, it is proposed that future personnel have a firm grasp on both startup and construction testing.

Access to the plant and security is greatly tightened to the levels required for operating a nuclear power plant. The NRC grants permission to load fuel. With the present fleet, the operating license was granted with permission to load fuel although future plants will probably already have an operating license.

Startup testing is a graded approach of sub-phases. Normal plant operating procedures are used to operate the plant and specific tests are conducted using test procedures. The Technical Specifications, the legal rules that govern plant operation, are imposed and must be followed unless specific exemptions are granted from the NRC.

The initial, or first, core is loaded. New un-irradiated fuel is only slightly radioactive so the refueling canal was often not flooded to the normal refueling levels required for highly radioactive fuel. A dry canal facilitated repairs on the fuel handling equipment and placement of temporary neutron detectors in the core.

Pre-critical hot functional testing then verifies the reactor coolant system and other support systems are ready to support a critical core. This phase begins after the core has been loaded.

The reactor vessel and head are assembled, reactor coolant system is filled and vented, the control rod drives are energized and checked, the time required for control rods to insert into the core following a scram is measured, the reactor coolant system is again heated by operating the reactor coolant pumps, and tests involving parameters that have changed with the core in place are conducted. For instance, in pressurized water reactors, measurements are made of the flow rate provided by the reactor coolant pumps and the rate flow decreases when the pumps are de-energized and the rate at which reactor coolant system pressure is increased and decreased. A baseline radiation survey of the plant is conducted.

Initial criticality occurs with the reactor coolant system at hot standby. The reactor core is brought critical for the first time in a carefully controlled manner. In most pressurized water reactors, the control rods are first withdrawn to a predicted critical position but the core remains slightly sub-critical because the boron concentration in the reactor coolant is high. The boron concentration is then slowly reduced (diluted) to the point that the core is critical. Boiling water reactors do not normally use boron and are made critical by positioning control rods.

Initial criticality leads to low power (core) physics testing, conducted to verify the core is correctly assembled and conforms to predictions. Criticality occurs at an extremely low power level and the core's power level is increased to the point where neutron detectors outside the core provide enough signals for their associated computers to determine changes in reactivity from the rate of change of neutron flux at the detectors. Power is raised several decades above criticality but is below approximately 0.1% power, the point where significant amounts of nuclear heat are generated. This low power, or zero power, condition minimizes the powerful nuclear fuel feedback to facilitate verifying proper behavior of the core without significant feedback. Predicted values are compared to measurements of the reactivity worth of the control rods, moderator temperature coefficient, and overall (isothermal) temperature coefficient, and in pressurized water reactors, boron concentration. Predictions of the core's power distribution are compared to measurements called flux maps, taken with movable or fixed detectors located in the core, to verify that the control rods are connected to the mechanisms that move them and the core has been properly assembled.

During hot functional, initial criticality, and low power physics testing, in pressurized water reactors, heat from the reactor coolant pumps and the core is rejected through the steam generators to boil water that is supplied by the small auxiliary, or emergency, feed water pumps. Steam is dumped to the atmosphere or to the condenser.

At the successful completion of low power physics testing, reactor power is raised above 5% power, the lower limit for power operation. The supply of feed water is transitioned to the main feed water pumps from the auxiliary feed water system. At about 10% to 15% power, steam is admitted to the main turbine and its speed is increased in a series of steps to synchronous speed (1800 rpm). The turbine's controls and trips are tested. The generator's field is energized and its controls are tested. The generator is synchronized and connected to the grid.

The remainder of testing occurs in a series of four increasing power levels, typically 25%, 50%, 75%, and 100% of full power. The core tests at each power level, or plateau, include flux maps, measurements of coolant boron concentrations and comparisons with predictions, and measurements of radionuclide levels in the coolant. At some plateaus the Doppler (power) coefficient may be measured. The nuclear instruments associated with the nuclear detectors outside the reactor vessel are adjusted to accurately reflect axial core power shapes and power level. Core thermal power level is measured. The secondary plant is tested. Limited power changes are made to facilitate adjusting control systems, identify equipment malfunctions, and provide benchmark data for computer codes including the operator-training simulator.

The plant is tripped at the end of each power plateau to assess the response of the plant, demonstrate that the plant, including the buildings, piping restraints, and other structural components, can withstand trips and transients without damage. Important trips include a total loss of offsite power, a trip of the turbine, a trip of the main generator, and in some plants a total loss of forced reactor coolant system flow and transition to natural circulation.

The end of startup testing is normally marked by a period of steady-state full power operation for a given time, typically 100 hours, called a 'warranty run' whose completion signals the beginning of commercial operation.

A few months are then required for test personnel to complete the documentation including writing a Startup Report to the NRC.

In short, construction testing prepares components and systems for operation and occurs mainly during construction after components have been assembled into systems. Startup testing occurs after the components have been tested and brings the plant from fuel loading to full commercial power in a programme of ever-increasing power levels and complexity. Startup testing ends with commercial operation.

6. EARLY COMMISSIONING STAFFING APPROACHES

Utilities (operating organizations) are responsible for the construction, startup, and operation of nuclear power plants. The normal staffing levels of most utilities are not large enough to support the construction and startup activities including startup testing. In the past it was cost-effective to hire outside experienced personnel for construction and startup testing.

In early US nuclear plant startups, a few people traveled from plant to plant and gained experience and knowledge. Although some remained with the utility after the startup, the majority left for other plants, taking much of the experience and knowledge they gained during the startup with them. It is advisable to consider retaining these knowledgeable personnel at the plant after startup or to thoughtfully spread their expertise throughout the industry so as not to concentrate this knowledge in just a few individuals. A startup is a unique opportunity to learn and apply engineering and managerial skills that prepare people for much greater responsibilities. This should be a primary consideration in the development of this critical people resource in light of the strategic role of nuclear power and extended period required to construct and start plants as well as the number of plants being anticipated. To put this in perspective, the span of workforce planning required for just the reactors being proposed in the US today (December 2006) is over 25 years. This duration of workforce planning is not typical of any industry other than nuclear power.

A limited survey of several US nuclear utilities indicates they are considering the need for startup engineers in a general way, but not with a specific focus. A manager at one utility with no plans for a new plant mentioned that about half of the operator trainees are young degreed engineers and they would like the experience of a startup. One utility, with recently announced plans to build at one of its sites, will use this event to train its younger engineers in anticipation of building more plants.

A limited survey of non-utility organizations indicates most have not considered the need for training startup engineers because they perceive the need to be too distant. The impression is the non-utility organizations are waiting to react to the expressed needs of the utilities. This may create delays in getting people properly trained prior to the need for resources; an issue of timeliness that could lead to delays. This is, again, dependent on how the initial plant startups are conducted. There are two approaches. One is the traditional approach of segregating construction and startup (as was done for the current plants under the, now defunct, two step licensing process). There may actually be a need to default initially to this approach if sufficient personnel cannot be identified. The other is the new approach identified in current US regulations that integrates all aspects of construction and startup including involvement with certain aspects of the manufacture of components.

7. NEXT GENERATION PLANT COMMISSIONING TRAINING - A SYSTEMATIC APPROACH

From the previous descriptions and accounts it is clear that training on the job or in multiple ways by different entities using several different standards is likely not the most efficient approach to developing these talents. There are, of course, differing regulatory, business, and governmental structures to be considered when proposing any “system.” This will be the case with the following information as well. What follows are considerations to be made in how to establish a practical, less costly, systematic and sustainable programme of personnel development to ensure that the critical aspects of commissioning are communicated and the capabilities and performance of those leading these efforts is known before startup activities begin. In short, the effort must transcend utilities, vendors and regulators such that a common language is developed before startups begin not developed once in progress. It must, therefore, be systematic. A national entity that can work with all three without conflict is recommended. In the US, the Idaho National Laboratory is being proposed based on its nuclear research and development mission and its relative independence from the regulator making it an ideal location to host all parties involved.

The following sections describe the training process and content. Following that is a description of the parties involved and how they will be engaged in this systematic and systemic approach to commissioning training.

8. TRAINING STRATEGY

The programme provides an effective curriculum to facilitate transferring knowledge, skills, and attitudes from the successful experienced startup engineers to the new engineers. Options to be considered include distance learning, mentoring, simulator training, training on mockups of components and systems, webinars and role-playing.

A mentoring programme is one part of training, which also involves distance learning, direct contact during the lab environment, and presence at plants during startups. Mentoring makes the most efficient use of the limited number of experienced engineers. A significant resurgence in the nuclear industry would lead to parallel construction and startups which would quickly absorb the remaining active experienced construction test and startup engineers and leave few resources available to train the additional new staff.

9. TRAINING CONTENT

There should be two general groups of cross-trained engineers, those focused on engineering and those more interested in project management.

All would understand construction and startup testing and how the components, systems, and entire integrated power plants operate, the legal (Technical Specification) foundation for plant operation, and plant operating procedures, an abbreviated version of typical training reactor operators.

All would understand root cause failure analysis, writing and executing test procedures including a depth and breadth of understanding of the acceptance criteria and how it is generated, technical writing, schedules, and budgets. Lessons learned from past mistakes and good practices would be emphasized.

Of particular importance are the construction test engineering skills of handling the equipment and leaving it (laying it up) in a manner that prevents it from being destroyed while it is idle (for instance, avoiding microbiologically induced corrosion).

Additional managerial skills would include supervision of crafts and technical people, interaction with regulators, upper management, and others under relaxed and stressful situations, conducting productive meetings, team building, and public relations, particularly speaking with the press.

The training facility should have a control room simulator (or several) that would generically represent the new plants with their small control rooms and small displays. A simulator is a powerful training tool because it can accurately represent the highly interactive nature of a power plant. It also allows validation test procedures and data analysis techniques, and facilitates role-playing, and encourages familiarization of new students with a power plant.

There should be several laboratories where people can thoroughly learn about equipment and construction testing of components and systems. One goal would be to offer experience with motor operated valves, air operated valves, circuit breakers, computer control and protection systems, and piping systems. Another goal would be to provide limited and controlled demonstrations of what can go wrong, for instance water hammers, locked motors, binding valves, improperly aligned motors and pumps, excessive vibration, and other problems.

Automation and greatly increased instrumentation will undoubtedly be part of the initial design of power plants to monitor the operation of equipment and facilitate identification of needed maintenance. The engineers should be familiar with the instrumentation and its use and limitations. A goal is for an instrumentation laboratory to demonstrate how various instrument systems are designed, how their components are calibrated, operated, and how to recognize damage.

10. AN INSTRUCTIONAL PROGRAMME IS ANTICIPATED TO INCLUDE THE FOLLOWING GENERAL CURRICULUM:

- Components and systems, from a first-principal standpoint, including likely failure modes and symptoms
- System interactions and integrated plant operation

- Control theory and application, including man-machine interfaces, common-mode failures, and instrumentation and control
- Root cause failure analysis/evaluation
- Nuclear engineering as it applies to plant startup including fuel damage
- Plant design, design assessment, acceptance criteria and its development, and the implications of accepting equipment performance that does not meet acceptance criteria
- Interaction of the plant with the grid, communicating with grid operations
- Test procedure writing, taking and evaluating test data, writing test reports
- Project management (scope. schedules, budgets, impact of variance, resource utilization, basic understanding of financial issues)
- Succinct and complete report writing
- Effective interpersonal and leadership skills
- Understanding and addressing the needs/concerns of test team members, management, quality control, operations, maintenance, regulators, others
- Analysis of historically successful and unsuccessful test programmes
- Review and interpretation of common startup problems/issues
- Human Performance Fundamentals
- Conduct of Operations including situational awareness and attention to detail
- Effective methods for finding and retrieving information on past and present equipment and plant problems
- The status of the nuclear industry
- Construction and Operating Licensing; including environmental considerations
- Public affairs
- Developing a fundamental attitude of curiosity and questioning
- Utilizing industry resources (EPRI, INPO, and NRC information and databases)
- Developing a network of colleagues at other nuclear plants
- Knowledge and skill preservation/capture and transfer to the operating organization

11. TRAINING METHODOLOGY

Distance learning presently appears to be the most attractive option to train people. It would involve televised classroom sessions to all participants, including regulators. Modern data compression techniques facilitate distance learning as an inexpensive, convenient method of wide-scale instruction. The distance learning is anticipated to require one hour every weekday and an hour of homework for every hour of class.

An important complementing component would be weeklong focused sessions at the central facility approximately every other month where skills learned during classroom could be practiced. During these focused sessions it is anticipated that emphasis will be given to project management and interpersonal skills. The generic plant simulator would facilitate the understanding of plant transients and the operation of the core. Experienced mentors would be available to provide guidance and assistance in skill acquisition.

To preserve the distance between the regulated and regulators, the regulators would be trained in separate sessions but at the same schedule so the overall training schedule is maintained.

The goals of the programme are to: (1) Produce an industry-wide group of well-trained construction test and startup engineers with demonstrated and qualified knowledge, superb technical and interpersonal skills, and industry-wide contacts; and (2) Provide opportunities for personnel from all aspects of the nuclear industry to participate in startups.

The anticipated short-term main benefit of well-trained engineers is a smooth, fast, and reasonably trouble-free startup.

The anticipated long-term benefits of providing opportunities for a wide range of people to participate in startups include a higher level of knowledge, a better understanding of the challenges and issues facing utilities during construction, startup, and operation, better management skills, better communication among many more people throughout the nuclear industry, an industry-wide pool of talent for future startups, and a better trained and more stable startup and construction testing work force.

12. THE PARTICIPATING/AFFECTED ORGANIZATIONS AND INDIVIDUALS

Students

The minimum education requirement of a BS degree, and for engineers having at least passed the Fundamentals of Engineering examination, lays the foundation for the high level of technical skills and a demonstration of the necessary engineering aptitude, work ethic, ability to learn at a rapid pace, and time management.

Utilities

The main goal of the Programme is to provide trained, qualified staff to augment the utility's staff during startup. The majority of people would be drawn from other utilities.

The project management and engineering skills and experience gained during startups have benefited many in the present fleet of nuclear plants. The utility personnel who participated in startups gained priceless engineering knowledge, operating experience, and managerial training that have been invaluable in preparing many corporate leaders for positions of increased significant responsibility and authority.

A secondary objective is to facilitate hands-on opportunities to participate in startups at other plants for engineers from all plants, including those with no immediate plans to build plants. Utilities invest considerable time and resources in new employees, who will naturally want to participate in startups.

The Programme would help place engineers in a staff augmentation situation with the expectation that they would return to their home organizations where their knowledge, experience, and contacts will be appreciated and used. Although beyond the scope of the Programme, it is hoped that when startup engineers return, they will be offered positions that will utilize their experience and provide enhanced opportunities, in contrast to the fate of most of the older startup engineers.

Regulatory bodies

A goal of the Programme is to facilitate opportunities for the individuals from the regulatory bodies to gain startup experience by observing and working with the plant's resident inspector and startup specialists within the regulatory body.

A strong nuclear industry requires a knowledgeable and experienced regulatory workforce. As an example, the USNRC is staffing up to replace attrition, mainly by retirement, and to meet the demand for Construction and Operating License (COL) reviews. Plans were announced in

September 2005 for the NRC to hire 350 entry-level and experienced workers starting in FY 2006.

As mentioned earlier, training would involve the same distance training as the others but separate training sessions at the central facility to limit friendships and associations that might compromise the necessary distance between the regulators and regulated.

Architect/engineers

The quality of the present US fleet of plants improved remarkably as various offices of the A/Es became quicker and better in designing. Improvements and design changes from earlier plants seemed to be very slow in being applied to the later plants. One of the great values of the startup engineer was his knowledge of lessons learned and design mistakes at the plants he had started up so it could be corrected with the next plant. From the perspective of the startup engineers, the poor feedback process within the A/Es for identifying and correcting design shortcomings guaranteed ample and full employment at considerable expense to the utility through avoidable rework, reconstruction, and delays.

By the very nature of their businesses, the A/Es and vendors have a narrow focus that concentrates on their particular equipment or design. Much can be gained by training selected A/E and vendor personnel in the much broader perspective and needs of integrated plant operation. The training and integrated involvement with the Programme should be considered as an essential aspect of total quality control.

A crucial aspect of the Programme will be the rapid communication of information with startup engineers at plants. As part of rapidly transferring the crucial lessons learned, the Programme would establish a focused database on problems specifically encountered during construction, startup testing, and initial operation. Some problems are well known and will be included in the construction and startup engineer training. Examples include the microbiologically induced corrosion of stainless steel piping mentioned earlier, recycling water at the plants to ensure adequate quantities for flushing and cleaning systems, and special equipment to mix the large quantities of boric acid required just prior to loading the initial core.

Universities

The involvement of universities in a startup, even in a peripheral way, could be a superb recruiting tool for the nuclear industry and will provide valuable experience and focused insight to students and faculty. The Programme envisions finding appropriate avenues and opportunities to involve personnel and facilities of universities, particularly local institutions, in engineering and radiation protection, project management and business.

Foreign entities

One goal of the Programme is to evaluate and develop effective ways for greater presence with the world nuclear community. There is mutual benefit for all parties in participating in startups, both foreign and domestic. The Japanese, Chinese, French, Koreans, Finns, and others have recent startups, are building and starting up plants, or are seriously considering new plants. The South Africans and Chinese are actively investigating pebble bed high temperature gas cooled reactors. Presence at a site greatly enhances the mutual influence, cross-fertilization, and the eventual realization of better products and practices.

At some point, there may be cause to engage the international community via IAEA or other international venues with the hope of information sharing and, potentially, creating a Startup Engineer Body of Knowledge and reference infrastructure and, possibly, a universally recognized certification.

13. BENEFITS OF A SYSTEMATIC AND SYSTEMIC TRAINING PROGRAMME TO INDUSTRY

This systematic training approach is aimed at supporting the six to eight month durations envisioned for first-of-a-kind plants and considerably shorter startups for follow-on plants. Historically, the last US plants enjoyed far faster startups with many fewer problems. Reduction was due to better, more complete designs by the architect-engineers, shortened test programmes, and more experienced construction and startup test staff. The goal is to do as well with the first of the new plants as the last of the present fleet.

There is no shortage of bad examples from the old days. As an extreme example, one startup required 18 months (545 days) due to equipment and design problems, a large amount of testing associated with being a first-of-a-kind plant, and the misfortune of having the post-TMI requirements imposed during construction. An essentially identical follow-on plant at the same site required 11 months (322 days). Several years later, abbreviated programmes at later plants required approximately 4 to 5 months (120 to 150 days). Experience and simplified test programmes can quickly and safely bring a plant to commercial operation.

The cost of delay in bring a plant to commercial operation is estimated to range from $500,000 to $1,000,000 per day. Equipment and testing problems can result in losses of many millions of dollars, making nuclear power less competitive and discouraging further investment.

In the opinion of some of the senior engineers interviewed, the Three Mile Island accident resulted partly from a poor startup test programme where equipment problems were not adequately resolved and the staff was not adequately trained. Interestingly, TMI occurred during the overall transition from turnkey startups. The nuclear industry is far better trained, disciplined, and regulated so it is highly unlikely that another TMI will occur, but it serves as an extreme example of the importance of a successful startup programme.

Trained personnel are one of many important keys to satisfying the unforgiving demand by the public and financial community for contained costs, realistic short construction, and reliable safe operation of nuclear power plants.

APPENDIX X
LING AO NPP COMMISSIONING (CHINA)

The Ling Ao Nuclear Power Company (LANPC) contracted to build the Ling Ao Nuclear Power Station (LNPS), two units of 1000MWe each, for which the Guang Dong Nuclear Power Station, (GNPS) is the Reference Plant. The LANPS units are located adjacent to the GNPS units on the same site. The project is directed by the policy "Safety First, Quality first" and the Three (Quality; Schedule; Investment) Control Objectives. GNPS Units 1 and 2 began commercial operation in February and May 1994, respectively, and LNPS Units 1 and 2 began commercial operation in May 2002 and January 2003, respectively. The construction and commissioning period for GNPS units were about 6 years, and about 5 years for LNPS units.

1. OBJECTIVE FOR LANPS STARTUP WORK

The LING AO project, startup work had the following objectives:

— To accomplish startup work basing on "Three Control" and directed by "Safety First, Quality First" policy.
— To effectively organize, carefully commission and intimately cooperate so as to accomplish transmission steadily and establish a reliable base for safe operation.
— To push forward the "self-reliance" process by promoting a group of personnel who are qualified in management and technology. Through the practices of LNPS commissioning, to find a management mode that is suitable for Chinese specific situations.
— To take advantage of technical capabilities in China so as to set up a stable technical support system for commissioning and operation.

2. MISSION OF STARTUP PREPARATION

The following preparation was completed before single-system commissioning:

— to organize a startup team which was united, devoted, and competent for its assigned tasks,
— to work on the weak points and characteristics of LNPS commissioning by making full use of experiences gained during GNPS commissioning,
— to plan for startup organization and personnel arrangements,
— to appoint startup attendants in coordination with related units and to complete Chinese personnel recruitment accordingly,
— to complete training and authorization of Chinese personnel on key posts,
— to set up domestic and foreign technical support systems in cooperation with related units,
— to define the scope and interface of the tests services to be contracted and sign the contracts or agreements concerned,
— to draft and approve the Startup Manual and other internal management procedures so as to build working channel with Contract Branches, Engineering and Procurement Management, Construction Management and Operations Department and Suppliers, etc.
— to work out Startup Level 3 schedule and to adjust it according to progress of erection,
— to study important commissioning items and to schedule tests,
— to define the drafting and reviewing responsibilities for relevant test procedures with concerned departments,

— to organize the Startup Interface Office,
— to set up and improve the computers system and startup document control system,
— to set up the procurement system for startup instruments and spare parts,
— to cooperate with the QA Department to draft the commissioning QA programme.

3. PRINCIPLES FOR STARTUP PREPARATION

The following principles were followed for startup preparation:

— Under the authority of Project Department, based on GNPS experiences and taking into account the project characteristics and regulations in relevant contracts, to accomplish startup work actively and efficiently so as to realize the general objective "according to the project schedule, to startup systems and equipment such that safe and fully-loaded conditions can be demonstrated".
— Using as a reference the GNPS startup mode, to set up a startup organization whose characteristics are consistent with LNPS project in order that startup work proceeds smoothly.
— Chinese personnel mainly consist of those from Project and Operations Departments and domestic technology support units. In order to more fully develop technical personnel, as many operation preparation personnel as possible should participate in the startup. Although the majority of the personnel are appointed from Project and Operations Department, operation preparation personnel have priority to take on some critical technical positions.
— Training should follow the principle "use on site and domestic conditions as much as possible to learn; organize training abroad only in the case of need and possibility". Trainees can only manipulate equipment after being authorized.
— In the course of writing and implementing of the Startup Manual, the Startup Team should enhance communications and cooperation with all concerned parties including Project and Operations Preparations.
— Through relevant experiences, clearly analyze the key routes and technical problems in startup tests in order to be prepared for any changes and adapt to them promptly. Work process should be regulated so that the startup mission is completed safely with high-quality.

4. WORK ANALYSIS AND PREPARATION

(1). Characteristics

LNPS had the following distinctive characteristics regarding startup:

— 23 Chinese personnel assumed responsibilities of Test Supervisors at the beginning of startup.
— The LNPS project schedule, provided 44 months from the beginning of single-system startup for unit 1 to the end of performance tess for unit 2 (July 1999－Mar. 2003)
— After nuclear steam generating in NI, CI overall startup was on the critical path for startup.
— LNPS not only included technical improvements over GNPS in engineering and construction but also included advanced technology in some crucial systems and instruments. Moreover, some NI & CI instruments were manufactured in internal factories and a process from engineering to manufacturing of the BOP was realized in China.

— In order to be more experienced, personnel of operation preparation comprehensively participated in the startup.
— Key personnel were trained mainly in China.

(2). Human Resource Preparation

Because of the principles and characteristics above, preparations needed to be made regarding organization, team improvements, personnel training, technical following-up, technical support and personnel management, especially on specific training concerning promoting Startup personnel's ability to operate on site, and drawing up practical training programmes and plans. The following strategies were taken:

— A Deputy Project Manager was appointed to be Startup Manager concurrently in order that he had sufficient authority in dealing with departments and contractors.
— A group of personnel experienced in GNPS project and operations took lead roles in Startup Management Branches and Sections.
— Key personnel were strictly selected and trained. Those knowledgeable of the technology and ideology of GNPS were definitely needed. A qualified, united startup team with realization of the importance of quality was set up through: training in domestic power stations under commissioning; participation in a foreign contracted NPP project (Chasma NPP in Pakistan); and in domestic training centres.
— In the course of more than one year of startup preparation, coordination and communication of startup personnel were strengthened in order to establish a sound working atmosphere.
— To make a detailed study of design characteristics and follow up the manufacturing schedule of main components.
— To study the difference between LNPS and GNPS so as to absorb the useful experiences. To attend manufacturer-organized training and to anticipate potential problems in startup in order that problem solving abilities are developed.
— To make a detailed study of the LANPC Supply Contract, PC Contract, and Erection Contract in order to take effectively learn from Contractor personnel and technical resources. Within the scope of PC contracts, some experts took part in startup preparations, Chinese personnel studied GNPS experiences, became familiar with LNPS systems and commissioning documents, followed up on erection processes and familiarize themselves with the site. In a word, the purpose was to promote the practical ability of startup personnel.
— To define strict and systematic evaluation and authorization procedures. 20 potential young technicians were trained through participating in the Chasma NPP commissioning. The organization, scheduling and coordination of other short-term external training were centralized.
— In order to learn external experiences and set up a domestic commissioning team, Chinese test supervisors took some important system posts working together with expatriate test supervisors. Chinese personnel were to take as many responsibilities as possible for LNPS Unit 2 commissioning.
— Based on the experiences of GNPS, to prepare carefully for the Startup Manual drafting in order to improve work efficiency during commissioning and to accomplish startup activities with high quality and standards.
— To set up an integrated technical support system with the help of higher authorities. EPM, and CPM, and with the cooperation of domestic technical support units.

— To set up comprehensive management objectives surrounding the centre of Three Control, including safety and technology, scheduling, investment, technology, and processes.
— To improve procurement management according to LNPS and GNPS cooperation contract and to make use of all the usable resources including GNPS advanced technology and experienced personnel.

(3). Three periods of Startup preparation

Startup was divided into three stages: preparation, single-system tests and overall commissioning. The last two stages were also named practical periods and the first one is their prerequisite.

In order to put emphasis on preparation, three periods are divided before single-system tests:

— First period (1997.08–1998.03): Organization and key personnel training. To make a plan for Startup Team organization, management mode, management objectives, training programmes and schedule, and personnel assignment.
— Second period (1998.03–1998.12): Documentation and technology preparation. To finish Startup management documents drafting, three level scheduling and to make clear the measurements about technical management, service and support.
— Third period (1999.01–1999.07): Personnel training, authorization before taking posts, schedule development and materials preparation. Emphasis was put on training and authorization that was common for all of most Startup personnel, developing process schedules and preparation of Startup instruments.

5. STARTUP TEAM ORGANIZATION

The Startup Management was composed of:

3 operational branches:
- — NI Startup Branch (NIS)
- — CI & BOP Startup Branch (CBS)
- — Electrical and I&C Startup Branch (EIS)

2 functional branches:
- — Administrative & Technical Branch (ATB)
- — Startup Supervision Engineer Branch (SEB)

6. ARRANGEMENT OF PERSONNEL POSTS

Total assignments: 226 persons (short-term assignments of <6 months excluded) 162 Chinese and 63 expatriates. In the supplier's contract, 34 qualified expatriate test supervisors were appointed. Considering this, Startup Management allocated corresponding Chinese test supervisors to each branch in order to follow up the startup test implementation on site and realize in all aspects "self-reliance in startup". Through this experience, Chinese Test Supervisors were able to take more responsibilities in the commissioning of unit 2 and be prepared to become Startup Supervision Engineers for overall tests of units 1 and 2.

7. TRAINING LIST OF KEY CHINESE POSTS FOR STARTUP:

> NOTE: In the remainder of this Appendix there are a number of acronyms used for job positions that are specific to this project. It is not necessary to understand these acronyms in order to appreciate the training opportunities provided for project personnel. Thus, no attempt has been made to provide definitions for these acronyms.

For key Chinese posts, training requirements for Chinese were clearly defined. These key posts total 59, of which 20 participated in commissioning of the Chashma NPP in Pakistan (12–18 months) and the other 39 were divided into two groups to be comprehensively trained on management or technology (about 12 months). Additionally, some other personnel had specific technological training (in China and abroad).

(1) List of Startup Personnel Participating in Training in Pakistan (20)

Group Leader
RCP/NET/TUY Test Supervisor
RRA/VVP/GCT/ARE Test Supervisor
RIS/EHP Test Supervisor
PMC/RAD Test Supervisor
ASG/RAZ/SVA/EHS Test Supervisor
EAS/RRB Test Supervisor
RCV/SEC Test Supervisor
TEP Test Supervisor
High voltage electrical Test Supervisor Assistant
LHP/LHQ/BAS Assistant Tester
SE*/SD*/SHY/SAP/XCA Test Supervisor
EBA/ETY/EV*/DEG Assistant Tester
KRT/KZC Assistant Tester
RGL Assistant Tester
RPN/RIC Assistant Tester
SIP Assistant Tester
RRC Assistant Tester
Logic and Control Assistant Tester
GGR/GHE/GFR/SKH/GTH Test Supervisor

(2) List of Personnel Participating in Comprehensive Training

The first group (16)
Startup Manager
Deputy Startup Manager
Assistant Startup Manager
Heads and Deputy Heads of Operational Branches（NIS/CBS/EIS）(7)
Head of Startup Supervisor Engineer Branch
Head and Deputy Head of Administrative and Technical Branch (2)
Head of Technical and Scheduling Section
Head of Test Documentation Section
Head of Performance and Testing Device Management Section

The second group(23)：
Head of NSSS Section
Head of BNI Systems Section
Head of Waste Treatment Systems Section
Turbo generator system Section Head
GRV/GST/GRH Test Supervisor
GPV/GCT/VVP/CET Test Supervisor
GEX/GSY/GPA Test Supervisor
Turbine Hall Auxiliary Systems Section Head
BOP/APP/APA Test Supervisor
Head of Feedwater Systems Section
CEX/ATE Test Supervisor
GSS/CVI Test Supervisor
ABP/ACO/ADG/AHP Test Supervisor
Head of Electrical Systems Section
GEW/LGR/GEV/GSY Test Supervisor
Head of BOP Systems Section
DW*/DV* Test Supervisor
Analog Control Instrumentation System Section Head
REN/SIR/SIT Test Supervisor
GRE/GME Test Supervisor
Logical Control Instrumentation Systems Section Head
SE*/SD*/SHY/XCA/SAP Test Supervisor
Engineer for Test Preparation and Analysis

(3) List of Personnel Participating in Specific Training in China or Abroad

(1) Abroad：
PMC Test Supervisor
RCP Pump Test Supervisor
RCV Charging Pump Test Supervisor
VVP/GCT Valve Test Supervisor
SEBIM Test Supervisor
Main and Auxiliary Switchyard Test Supervisor
DMR Test Supervisor
KIT Test Supervisor and Assistant
RIC Test Supervisor and Assistant
CI/P320 Test Supervisor and Assistant
SIP Test Supervisor and Assistant
GRE Test Supervisor and Assistant
APP/APA/APD Control Test Supervisor and Assistant (2)
Multi-stud tensioning Machine (2)
CFI/CRF Test Supervisor
Super-compactor
Overall test Performance Evaluation Training in EDF

(2) Domestically：
A. Xi An Thermal Power Research Institute: for the training of turbine thermal performance and vibration measurement. (14).

B. Suzhou Valves Factory: for Motor driver or Pneumatic valve commissioning training (17).
C. Shenyang Pump Factory: for training (15).
D. Luohuang Power Station: for commissioning training (20).
E. Eastern Turbine Factory: for commissioning training (6).
F. NPIC: for system circuit training (20).

8. EXAMPLES OF RESPONSIBILITIES FOR KEY CHINESE AND EXPATRIATE POSTS

Startup Manager

The Startup Manager post was held by a Deputy Project Manager concurrently. He was responsible for management of startup personnel, directing the startup branches and sections, coordinating with other departments. He had the overall responsibility for startup quality, safety and schedule, and in particular:

- to make a plan for personnel assignment and recruitment,
- to review and approve Startup management procedures,
- to approve and adjust startup schedule,
- concerning the range of activities, he is to coordinate in the course of dealing with higher authority, contractors and departments of Project and Operations,
- to approve startup procedures and test reports,
- to organize meetings of Site Testing Committee,
- not only to approve and issue documents of Startup Management but also deal with documents received,
- to give authorization to test performers,
- to manage QA activities in the course of startup

Startup Branch Head of operational branch

Under the authority of the Startup Management, the Startup Branch Head of an operational branch was responsible for management of startup activities within his branch including:

- organizing the related startup activities according to the authorities of the Startup Manager and progress of startup schedule,
- assisting Startup Manager in organization and coordination fields,
- writing Startup Manual and other management procedures in the scope of his branch,
- relations with other teams and branches,
- preparation and implementation of training programme of his branch personnel, and participation in the training for startup personnel,
- preparation of level 3, level 4 and rolling schedule, and target commissioning schedule,
- organizing update of test procedures of tests in his branch scope according to the actual status of the systems,
- ensuring the application of safety rules within his branch,
- review of the test reports prepared in his branch,
- approves all work permit requests and test permit requests before transmission to Operation Branch,
- evaluation of his branch personnel and proposing authorization of test supervisor,
- verifying and strictly control of the implementation status of the contract by the contractor’s personnel.

Branch Head of functional branch

Under the authority of the Startup Management, the Administrative and Technical Branch Head and the Startup Supervision Engineer Branch Head were responsible for organization and management of all activities of their own branch, in particular:

— Administrative and Technical Branch Head

- setting up and improvement of documentation management and computer management system in Startup Team,
- verification and quality control of all testing documents in Startup Team
- Coordination of preparation of startup schedule by branches,
- writing of Startup Manual and other management procedures according to the request of the startup management,
- follow-up of contracts related to Startup Team,
- follow-up of insurance claims during commissioning,
- assistance to the startup management for the preparation and discussion of related documents, especially for the preparation of Site Testing Committee,
- follow-up of external interfaces and management of the associated documents,
- follow-up and management of training and authorization of startup personnel.

— Startup Supervision Engineer Branch

- being responsible for all important test activities during overall test period, organization and management of on-shift activities, coordination with the Shift Supervisor on duty of Operations Department,
- organization of preparation of overall test schedule, writing of associated management procedure,
- overall management of Chinese and expatriate Startup Supervision Engineers,
- updating of overall test procedures according to actual unit status.

Startup Section Head

Under the authority of his Branch Head and Deputy Branch Head, he took the responsibility of the front level management, and at the same time, the responsibility of startup engineer. He was responsible for all test activities of systems and equipment under his scope, in addition:

— to assist Branch Head, Deputy Branch Head for the administrative management of his section (office),
— to coordinate the relationship between Chinese and expatriate staff,
— to supervise the implementation of startup schedule and work planning of his section (office),

Assistants from PC Contractor (Project Consultation Contractor)

The responsibility scope and requirement for the Assistants assigned by the PC contractor are defined by the Startup Manager according to the actual needs of the project. Their basic responsibility included:

— to give suitable proposal and comments to all startup activities of the Startup Team and of the branches,

— to assist the Startup Manager and Startup Branch Head in coordination of all startup activities and review of technical documents, and to be in charge of the daily management of expatriate personnel,
— to assist the Startup Manager and Startup Branch Head in preparation of all startup schedules and send to the Startup Manager for approval,
— to assist the expatriate and Chinese test supervisors in analyzing and solving the technical problem and responsibility problem encountered during commissioning and startup.

Test Supervisor

The scope of responsibility of Test Supervisor in each branch is defined by the Startup Manager in liaison with the Branch Head in accordance with the contract, the procedure for the authorization and the actual needs. Test supervisors carry out the startup activities of the systems and equipment in his scope. In the case where Chinese Test Supervisor takes the responsibility independently, his responsibility also includes that of expatriate Test Supervisor cited here below. When there are both Chinese and expatriate Test Supervisors, the contractual responsibility remains unchanged. Division of responsibility includes:

— Expatriate Test Supervisor

- to carry out the startup tests in the scope of authorization within conditions of test permit in accordance with the requirement of the contract and project schedule. The contractual responsibility that he takes during commissioning will not be changed for having Chinese Test Supervisor,
- to prepare the related test schedule and report in his section,
- to ensure the safety (for equipment and personnel) for the startup tests that he carries out on site,
- to prepare Clear For Action (CFA) test procedures according to actual system status on site,
- to supervise startup test maneuvers, to ensure the quality of the startup test on respecting strictly the test procedures,
- to fill and sign the test report exactly as it is, to check and evaluate the test results. If necessary, to propose complementary test to ensure that all criteria are reached by the test results,
- to analyze abnormal situation, and propose solutions.

— Chinese Test Supervisor

- to assist the expatriate Test Supervisor to carry out all startup tests according to written procedures,
- to follow up and control the implementation of test activities on site and the test schedule, and to report back,
- to learn and master the commissioning techniques and method of the related system and equipment. During unit 2 commissioning and startup, he will be able to take the same responsibility as the expatriate Test Supervisor except the contractual obligations for the equipment,
- to perform the QC function during the implementation of test and to check the truthfulness and correctness of the test report together with the expatriate Test Supervisor and sign.

- to analyze abnormal events of related systems and equipment and design changes from these events,
- to enhance the friendly cooperation between Chinese and expatriate personnel, to participate in the experiences exchange among the Chinese staff.

9. PERSONNEL ASSIGNMENT AND RECRUITMENT

Personnel assignment is an important task during Startup Preparation, particularly for key personnel.

Required Qualifications of Key Personnel

— They must be hard-working and ready to cooperate as a team,
— Conscious of the importance of quality and be capable of managing and coordinating,
— Be familiar with the relationships, prerequisites, key point and risks of startup activities,
— Have the ability to be responsible for nuclear and industrial safety,
— Be capable of using English at work and for communication.
— The Expatriate Assistants at all levels should take the basic responsibilities of preparing startup schedules and technical coordination.

Required Qualifications for PC (Project Consultation) contract personnel

They must have experience in startup management and technology, and be able to help Startup Manager and each Branch Head in scheduling, coordinating, technical analysis and responsible judgment. Moreover, the personnel experienced in GNPS project have the priority to be appointed.

Personnel Resource

Chinese personnel consisted of those assigned or recruited by Project Department/Operations Department/domestic technical support units. Key personnel mainly came from the Project Department and the Operations Department.

In principle, Chinese management and technical personnel in Startup Supervision Engineer Branch were assigned and rearranged inside the Startup Team at the proper times.

Demand for Chinese and Expatriate Personnel

The schedule of personnel appointment was adjusted according to the progress of the project. In principle, participants from the Operations Department took their positions according to the schedule taking into account the training time needed before taking their positions.

Demand Curve of Chinese and Expatriate Personnel

— Because 20 startup personnel will participate in the commissioning of Chashma NPP in Pakistan, the personnel demand in the earlier period will be increased in order to follow the project progress and the curve is higher comparatively.
— The curve includes the personnel demand and time arrangement to prepare writing of all kinds of documents. (from Aug.1998 to July 1999).
— Personnel demand at the peak between Dec. 2000 and June 2002.

10. TRAINING PROGRAMME FOR KEY STARTUP PERSONNEL

(1) Principles for the Training Programme

- To set up training programme for key personnel according to the required responsibilities.
- Learn the startup organization management in China or abroad in order to promote the abilities that Chinese personnel are short of, e.g., the ability to coordinate in scheduling and the specific commissioning technology. Among them, CI TS of each system will mainly be trained at projects still under construction in our country while NI Chinese TS of important systems will be assigned to participate in the commissioning of the Chashma NPP, in order to realize the object of being trained.
- To take the courses as required (i.e. common courses) either available in GNPS training centre or prepared by LNPS, eg, common courses for authorization or LNPS contracts, etc.).
- To be familiar with the station systems, the compositions, functions, periodical tests and relevant management of the equipments in the normal and transient operations of GNPS.
- To make use of the outage (about 8–10 weeks) studying not only the systems but also the operations and experiments on the equipments.
- To learn and add to the procedures and training materials of GNPS Startup Manual.
- In order to prepare for the future coordination, the liaison engineer of Operations Department may participate in the training for Startup Management personnel so that he can acquaint himself with the routine duties of Startup Team.
- To define and put into practice the evaluation measurements.
- To set up training archives for Startup Manager' authorization reference.

(2) Training Plan for Key Personnel

The training schedule for key personnel should meet the following requirements:

- Key personnel should be authorized and take their positions after training and 6-8 months before the commissioning of relevant systems.
- Other personnel should take their positions 4–6 months before the commissioning of each relevant system (including short-term training before taking positions).
- According to the training programme for key personnel and particular conditions of the personnel, to make a training plan for each of them.
- When necessary, to arrange for the Chinese Test Supervisor to participate in GNPS shift operations in order to increase their knowledge on site.
- To plan for establishing training centres in some factories in Suzhou, Chongqing, Chengdu, Shenyang in order to prepare fieldwork conditions for relevant personnel.
- To plan for participating in the startup commissioning of conventional power stations (Luohung power station in Chongqing).
- With valid certificates of the training centre, the courses having learned by trainees before may be considered as "equivalence" (excluding courses valid in a certain period).
- To appoint suitable personnel to make a plan for the fieldwork training, manage the training and help the trainees in study.
- The training plan should include objectives, content, time arrangement, requirements etc.

11. MANAGEMENT PROCEDURES AND EXTERNAL INTERFACES OF STARTUP TEAM

When the training was completed, under the authority of the Project Department and Startup Management, Startup key personnel finished writing the following procedures and documents (from Aug. 1998 to July 1999):

— Directed by the Startup Manager, to digest the experiences of GNPS startup management procedures and to write the Startup Manual taking into account LNPS startup characteristics.
— To assist EP to prepare the commissioning programme, test criteria and relevant documents before reporting them to NNSA.
— To appoint specific personnel to make the list of startup instruments and spare parts, to formulate management principles and to set up corresponding hard and software management system.
— As an important activity of startup organization, each Operational Branch prepares for its startup schedules according to the erection progress.
— In order to assure the correctness of startup documents and procedures at the beginning, to set up computer net and documents management system inside the Startup Team.

When realizing its responsibilities, Startup Team had these principal interfaces:

— Engineering and Procurement Management (EPM)
— Construction Management (CTM)
— Contract branches (SCB, CCB)
— Project Control Branch (PCB)
— Quality Assurance Department (QAD)
— Operations Department
— Maintenance Department
— National Nuclear Safety Administration
— Project Supervision Management of Supervision Company
— Suppliers (Framatome, GEC-A, BOP Suppliers etc.) and EDF
— External Support Units

The details about the interfaces above are described in the Startup Manual.

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