IAEA-TECDOC-1501

Human resource issues related to an expanding nuclear power programme

IAEA
International Atomic Energy Agency

May 2006

IAEA-TECDOC-1501

Human resource issues related to an expanding nuclear power programme

IAEA

International Atomic Energy Agency

May 2006

The originating Section of this publication in the IAEA was:

Nuclear Power Engineering Section
International Atomic Energy Agency
Wagramer Strasse 5
P.O. Box 100
A-1400 Vienna, Austria

HUMAN RESOURCE ISSUES RELATED TO AN EXPANDING
NUCLEAR POWER PROGRAMME
IAEA, VIENNA, 2006
IAEA-TECDOC-1501
ISBN 92–0–106106–4
ISSN 1011–4289

© IAEA, 2006

Printed by the IAEA in Austria
May 2006

FOREWORD

The IAEA Technical Working Group on Training and Qualification of Nuclear Power Plant Personnel recommended that the IAEA develop guidelines on human resource management (including staffing) and training/education programmes for new nuclear power plant (NPP) designs. This recommendation was made in recognition that these future NPPs may have significantly different needs in this area compared to operating plants, and if so, NPP operating organizations should integrate these needs into their planning for future NPP projects.

This report is primarily intended for use by NPP operating organizations that already have units in operation and that are considering adding to their fleet. Therefore, the addition of both new and current designs are addressed in this report. However, it should also be of value to those organizations that are considering the initial implementation of nuclear power, as well as decision makers in government, and in other nuclear industry organizations.

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. Particular thanks are due to C. Goodnight, United States of America for his assistance in drafting this report. The IAEA officer responsible for this publication was T. Mazour of the Division of Nuclear Power.

EDITORIAL NOTE

The use of particular designations of countries or territories does not imply any judgement by the publisher, the IAEA, as to the legal status of such countries or territories, of their authorities and institutions or of the delimitation of their boundaries.

The mention of names of specific companies or products (whether or not indicated as registered) does not imply any intention to infringe proprietary rights, nor should it be construed as an endorsement or recommendation on the part of the IAEA.

CONTENTS

1. INTRODUCTION

The purpose of this report is to disseminate lessons learned and information from nuclear power plant (NPP) operating organizations in Member States regarding human resource issues related to expanding a NPP fleet, with particular emphasis on expansions including the use of new NPP designs.

1.1. Background

In 2002, the IAEA Technical Working Group on Training and Qualification of NPP Personnel recommended that the IAEA develop guidelines on human resource management (including staffing) and training/education programmes for new NPP designs. This recommendation was made in recognition that these future NPPs may have significantly different needs in this area compared to operating plants, and if so, NPP operating organizations should integrate these needs into their planning for future NPP projects.

As this report includes the impacts on human resource management resulting from different technologies, it is useful to discuss some terms in this regard. The following are taken from IAEA-TECDOC-936, Terms for Describing New, Advanced Nuclear Power Plants. An **advanced design** is a design of current interest for which improvement over its predecessors and/or existing designs is expected. Advanced designs are further divided into evolutionary designs and innovative designs. An **evolutionary design** is an advanced design that achieves improvements over existing designs through small to moderate modifications, with a strong emphasis on maintaining design margins to minimize technological risks. The development of an evolutionary design requires at most engineering and confirmatory testing. An **innovative design** is an advanced design that incorporates radical conceptual changes in design approaches or system configuration in comparison with existing practice. Substantial research and development (R&D), feasibility tests, and a prototype or demonstration plant are probably required.

Another set of nuclear power technology/design terms currently in common use is the "generation" of the technology. The nuclear power industry has been developing and improving reactor technology for almost five decades and is preparing for new generations of reactors to fill expected orders. Generation I reactors were developed in the 1950–1960s and most are no longer in operation today. Generation II reactors are typified by the present US fleet and most in operation elsewhere. Generation III are the advanced reactors that are now being ordered and, in some cases, constructed. Generation IV designs are still on the drawing board and are not expected to be operational before 2020 at the earliest.

Designers of third-generation reactors generally have the following design goals:

- a standardized design for each type to expedite licensing, reduce capital cost and reduce construction time;
- simpler and more forgiving designs, making them easier to operate and less vulnerable to operational upsets;
- higher availability and longer operating life — typically 60 years;
- reduced possibility of core melt accidents;
- provisions to withstand core melt down accidents with limited effect on the environment;
- use of passive safety features, highly reliable active systems, or combinations of passive and active systems;

- higher burnup fuel to improve fuel utilization and reduce the amount of waste;
- burnable absorbers ("poisons") to extend fuel life;
- safety margins developed using probabilistic approaches.

It is intended that this report be relevant for the full range of NPP technology considerations, up to and including Generation III designs. There is no attempt in this report to specifically address Generation IV designs due to the lack of specific design details, and the long lead times before they are expected to be operational. However, it is expected that the general human resource issues addressed in this report will also have applicability for Generation IV designs. For near term situations involving the application of NPP designs that have already been built by NPP operating organizations for evolutionary designs, the guidance provided in this report is based upon actual experiences. For situations where innovative plant designs are being implemented, extrapolation from similar experiences is applied.

As indicated in IAEA-TECDOC-1362, Guidance for the Evaluation of Innovative Nuclear Reactors and Fuel Cycles, focused efforts have to be made to ensure that human resources are available to first bring about and then capitalize on the innovative developments that are the subject of proposed future NPP designs. While this may be a daunting task, globalization brings with it the opportunity to draw on a much broader pool of resources rather than striving to maintain a complete domestic capability across the many disciplines of science and engineering that constitute the range of technologies on which nuclear energy systems depend. International cooperation in science and development can assist with optimizing the deployment of scarce manpower and, just as important, the construction and operation of large scale research and engineering test facilities. Companies operating on a global basis can develop specialist teams that provide services to plants in many different countries. At the same time, the design and implementation of the future NPPs should seek to reduce the demand for skilled manpower for plant operations and support and routine maintenance. Examples include designing for maintainability, the use of modularity, smart components and systems, and computer-based operator aids.

To realize such international cooperation, plans need to be developed to retain existing knowledge and experience, to foster the sharing of science and development activities, and to strengthen multinational structures for education and development. The IAEA has already initiated such activities.

1.2. Objective

The key objective of this report is to provide guidance on human resource management (HRM), including staffing and training/education issues related to expanding an NPP fleet.

1.3. Scope

This report is intended to apply to the following NPP fleet expansion scenarios:

(1) Adding units of the same or very similar technology at existing sites.
(2) Adding units of the same or very similar technology at new sites.
(3) Adding units with considerably different technology (e.g. adding PWR units to a GCR fleet, adding an innovative plant design to an existing fleet, etc.)

These scenarios are listed in their order of difficulty regarding human resource related issues, with Scenario 1 posing relatively few uncertainties regarding human resource challenges, and Scenario 3 being the most demanding. Another factor that has considerable influence for all three scenarios is the time lag between commissioning of existing units and starting a new NPP project.

1.4. Users

This report is intended for decision makers, advisers and senior managers in governmental organizations, NPP operating organizations, technical support organizations and regulatory bodies in the countries supporting the expansion of existing nuclear power facilities, plants, and installations. The services of expert advisers and consultants may be needed for the various activities involved in the planning and implementation of human resources.

1.5. Structure

This report consists of two main sections. Section 2 addresses human resource issues, including staffing and organization, recruitment and retention, training and education, and work force planning. Section 3 addresses critical influencing factors that have an impact on one or more of these human resource issues.

1.6. How to use this report

Organizations considering expanding their nuclear fleet need information on the efficient and effective application of human resources. The information in this report can be used to supplement long and medium term human resources planning for an NPP project.

This report could be used as a companion to two IAEA reports that are expected to be published in 2006, one on the minimum infrastructure for a nuclear power project and the other on the potential for sharing nuclear power infrastructure. Additionally it may be used in conjunction with the IAEA reports identified in Appendix II.

2. HUMAN RESOURCE ISSUES

2.1. Staffing and organization

One of the human resource questions that will be of most interest to senior managers considering building and operating NPPs is the size of the staff required to operate and maintain the plant. This is the case because personnel costs are normally the largest component of operations and maintenance costs. Similarly, such decision makers will be interested in the extent to which the technology of the new NPP (relative to the technology of existing plants in its nuclear fleet) will permit integrating the workforce for the new plant with the existing workforce. As the number of units is increased, the organization structure may be maintained. For example, it may be feasible to have one maintenance organization for a site, with workers being capable of working, more or less, interchangeably among the units on the site. Many Member States have experienced as much as a 30 percent reduction in manpower requirements for the next reactor when maintaining an efficient organizational structure. Note, however, that “minimum staffing” levels are never actually achieved since some number of people will always be needed to account for emergent and/or variable work loads.

Additional factors impact human resource requirements. For example, when expanding production by implementing advanced nuclear plant designs that have fewer systems, structures and components, human resource requirements are reduced. Also, as the number of plant units increases, the opportunities for economically outsourcing activities also increase. To the extent that this is practical, the permanent plant staffing requirements may be reduced.

2.2. Recruitment and retention

Most NPP operating organizations have adopted a strategy for a new plant of staffing it with a mix of experienced personnel from existing plants in key positions, balanced with 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. The extent to which existing plant personnel can be used to staff key positions in the new plant will have an impact on the recruitment strategy. The redeployment of construction personnel into the operating and support staffs has also proven to be an effective strategy.

Advancement opportunities at the new NPP for existing staff may have an impact on attrition. Some people, particularly, high performers, are continually looking for new challenges and opportunities. The nuclear power industry makes a very large investment in the nuclear related workforce; oftentimes including several years of full-time training. Thus, it is particularly important in the nuclear power industry to retain these key staff. Some examples of retention strategies include:

- Developing plant and township infrastructure that is attractive to employees,
- Providing financial incentives,
- Educational support programs,
- Other programs for maintaining motivation.

A complicating scenario occurs when delays in construction of new plants is encountered. Effective approaches for moderate delays have been to temporarily reassign key personnel to functions in operating units while waiting for construction to resume.

Another issue occurs when existing plant personnel are attracted by the opportunities to advance their careers in a new technology. If too many people for the new plant are recruited from the operating plant organization, the operating plant performance may be jeopardized. Some Member States organizations have encountered this situation, and they report that this issue must be closely managed by senior management as they carefully plan for a balanced transition of experienced personnel.

2.3. Training and education

Preparations for the commissioning and initial operation of an NPP place the highest demands on training programmes, as essentially all personnel will need some initial training to be prepared to competently carry out their assigned duties. One of the key lessons learned in this regard is the importance of initial operator training including the use of a plant-referenced, full-scope control room simulator in operation well in advance of fuel loading. This simulator not only provides a unique tool for training control room personnel in carrying out their assignments, but also is important for such tasks as normal, abnormal and emergency operating procedure development and validation, development and validation of commissioning tests, and training of other plant personnel. For a variety of activities including engineering, design modifications, configuration management, and licensing, it is important to have competent technical support staff experienced both in operations and safety management. For countries that utilize part-task simulators during the commissioning period (before the full scope simulator is finalized), hands-on training in the control room of the commissioning plant may be used.

Basic safety features and their design bases for the new reactor should be included in the training programme. There can be considerable differences in the additional training needed to prepare experienced NPP personnel to take on a similar position in an advanced design plant. This consideration should be included in the decision making process for selecting the technology for additional units. Other considerations include the extent to which existing training facilities and equipment can be used to train the staff of the additional unit(s).

Some Member States have government sponsored/funded vocational training programmes that produce qualified maintenance technicians. These technicians typically have a basic set of mechanical or electrical qualifications. Under these conditions, plant-specific training occurs once the individual begins employment with the company. Additionally, competent persons from other related industries can be recruited into training programs for additional reactor plants. NPP operating organizations considering the development, installation, and operation of a new or additional NPP should consider their national training infrastructures.

2.4. Workforce planning

Life spans of nuclear power plants significantly exceed the work spans of a single generation of plant staff. This presents the challenge of retaining knowledge and operating experience as the work force ages and new generations of personnel are hired. This area, termed "knowledge management" is particularly important in establishing both information databases and the transfer of knowledge and experience to new personnel. This subject is treated in more detail in the IAEA publication Nuclear Power Industry Ageing Workforce: Transfer of Knowledge to the Next Generation (IAEA-TECDOC-1399).

To manage the transfer of key knowledge from one generation to the next, NPP management will need to have a workforce plan. Workforce planning is the process of ensuring that the right people are in the right place, and at the right time to accomplish the mission of the organization. More specifically, workforce planning is a systematic process for identifying and addressing the gaps between the workforce of today and an organization's human resource needs of tomorrow. The critical steps of workforce planning are:

Assess the current workforce. Determining what current key work force resources are and how they will evolve over time through turnover, etc.

Analyze the future workforce. Developing specifications for the kinds, numbers and location of workers and managers needed to accomplish the organization's mission, goals and objectives. This information will need to be developed in conjunction with the organization's strategic plans and budget requirements.

Identify gaps. Determine what gaps will exist between current and projected workforce needs.

Develop strategies to address gaps. These strategies may include recruiting, training/retraining, restructuring site organizations, contracting plans (for labor), technical competency-based assessments, leadership development, and succession planning. In addition, performance measures should be used to assess strategic progress.

For NPP operating organizations considering adding new nuclear units to its generation mix, workforce planning is a particularly important tool for several reasons:

(1) It can be used to assess the extent to which the current workforce can be effectively utilized for the commissioning and operation of the additional unit(s).
(2) It can provide a systematic structure for evaluating alternative plant designs from the human resources perspective.
(3) It can help to identify the expected gaps between the competencies of the existing workforce and those that will be needed for the additional unit(s).
(4) It can assist in developing a long-term strategy for the recruitment, training and staffing of the additional unit(s).
(5) It can provide insights into recruitment options from related industries and options for outsourcing of functions that had been conducted by internal staff.

To the extent that workforce planning is systematically implemented, plant personnel requirements needed to address the gaps identified through the above process, a more precise identification of needs can be justified. In many instances this is an informal or "best judgment" process where management has a "feel" for excess staff and that it will be sufficient for emergent needs.

3. CRITICAL INFLUENCING FACTORS

There are six critical influencing factors on human resource requirements for adding units to an existing NPP fleet that are addressed in this report:

(1) National/governmental infrastructure
(2) Owner/operating organization
(3) Site conditions
(4) Plant design/implementation
(5) Plant operations and support
(6) Stakeholder relations

3.1. National/governmental infrastructure

A number of national or governmental infrastructures' needs are planned to be addressed in an IAEA publication under development on the minimum infrastructure for a nuclear power project. Some of these infrastructures' needs will have human resource impacts and should be reviewed by Member States NPP operating organizations seeking to expand their nuclear programmes. The sharing of infrastructure for nuclear power programmes in Member States can be useful in economizing human resources for countries expanding nuclear programmes. This subject is treated in IAEA publications under development on potential for sharing nuclear power infrastructure.

Some significant issues related to national/governmental infrastructure that may impact human resource requirements are as follows:

- Requirements established by the national or local government for the siting and life-cycle of nuclear facilities
  - Minimum total land area requirements will impact security staffing.
  - Minimum distances from other facilities may require more work to be completed by in-house employees rather than vendors.
  - Minimum distances from population centres may impact shift staffing so that minimum emergency response times can be met.
  - Lifecycle issues related to a variety of areas that may impact human resource requirements, including the fuel cycle (open or closed), plant design life time, and decommissioning requirements. Each of these areas will impact personnel requirements for a variety of engineering and technical support areas.

- Laws established by the national or local government for environmental requirements
  - Environmental laws will directly impact the number, type, and frequency of environmental samples and analyses that will need to be conducted, directly affecting the number of personnel required to support these activities.
  - Environmental laws may also impact the number of facilities personnel due to grounds maintenance and water run-off requirements.
  - Environmental regulations regarding hazardous materials handling, processing, and shipment may impact staffing requirements in areas such as emergency planning and radioactive waste processing, shipping and disposal.

- National labour policy
  - Labour laws – Laws regarding the maximum allowable work hours per week, month, or year will directly impact the number of personnel required to perform many plant-related jobs, particularly those on rotating shift schedules.
  - Union/Organized Labour Law – Such laws will likely impact work hour requirements that unions/organized labour groups will attempt to apply to the NPP owner/operator, normally attempting to achieve a desired set of minimum staffing levels.
  - National employment policies – These policies may require certain diversities of employees (by race, ethnicity, gender, etc.) or minimum staffing levels that may directly impact the efforts of the NPP owner/operator to staff, hire, and retain key personnel.

- Nuclear education programs
  - Member States have developed internal nuclear education programs through government agencies, laboratories, and research facilities, helping to attract and develop initial expertise and experience in nuclear technologies.
  - Some Member States have developed nuclear programs at the university level, while others rely on other Member States to offer and maintain these types of educational programs.
  - At the NPP employee level, some Member States have developed nationally based training programs (operations, electrical and mechanical maintenance, and industrial safety, for example). Other Member States have the NPP owner/operators provide these types of training, directly increasing requirements for internal training personnel.

- Consideration of the manpower needed for public awareness plans
  - The degree to which the Member States' national government conducts public awareness/public communications programs may directly impact the personnel requirements of the NPP owner/operator to perform this function.
  - The level of effort required for public awareness/public communications by the NPP owner/operator will be directly proportional to (1) the level of support from the national government, and (2) the level of support or opposition from the public, both at the national level and at the local level.

3.2. Owner/operating organization

Nuclear operating organizations have a range of organizational structures, but typically have some common elements. There are two types of organizations that are designed to support either a single site NPP, or a fleet or group of NPPs operated by the same company. The common elements of each are discussed below:

Single site NPP – Where a single site NPP has a parent owner/operator, there are services and functions that are typically supported by the parent. These normally include information technology, human resources, public communications, and budget/financial services. Some companies also include the nuclear program in their parent organization procurement services activities that support purchasing, contracting, materials management, and the site warehouse. Although the personnel executing these functions report to a parent organization, they work at the NPP site location and have a "dotted line" reporting structure to an on-site manager. Where the NPP is a stand-alone operator, these infrastructure and support services personnel need to be included in site staffing plans.

Fleet/group of NPPs – Where an owner/operator owns or operates units at more than one location, a different organizational structure may be used to gain efficiencies. Many functions can be centralized in the parent organization, at least within a parent nuclear organization that supports all site locations. For example, within the United States' nuclear power industry, there are 19 commonly centralized functions for nuclear fleet companies:

- Budget/Finance
- Chemistry (programmatic)
- Communications/Public Affairs
- Employee Concerns Program
- Emergency Preparedness
- Engineering – Design Modifications
- Engineering Programmes
- Human Resources
- Information Technology
- Licensing
- Nuclear Fuels
- Outage Planning/Scheduling (for the fleet)
- Project Management
- Quality Assurance/Quality Control
- Radiation Protection (Programmatic & Dosimetry)
- Industrial Safety/Health
- Security (Programmatic, Access Control, Fitness for Duty)

- Procurement (Contracting, Purchasing, Materials Management, and Warehouse)
- Training (Programmatic, Curriculum Development, Testing)

While some of these personnel are located on site, all of them are members of the parent organization. Thus, the remaining activities are focused on direct plant operations, maintenance, and technical support. This approach allows for a smaller site organizational structure with fewer overall personnel needed to operate and support each NPP location. In the United States example, fleet nuclear companies have an average of 20 percent fewer personnel due to the economies of scale afforded by centralizing so many functions in the parent organizations. In such cases good communications between site and parent organization personnel are essential.

The owner/operator will also need to manage labour policies related to their personnel. Member States have significantly varied policies and relationships related to employees and organized labour. Overtime rules must be established and managed. These may depend on national labour law and radiation protection norms. The relationships between management and workers, including trade unions, need to be established, documented, and included in both budgetary and management plans. In a broader view, employment conditions need to be established based on the philosophy of the owner/operator and the culture of the member state, regarding “lifetime employment”, fixed term employment contracts, employment “at will” as well as for temporary personnel. These company-employee relationships will need to include defined benefits, salary structures, hourly wage rates, incentive programs, career development programs, etc. As the number and type of workers is established for the new NPP, total labour costs will roll up to become a significant portion of the operations and maintenance budget.

When planning for the addition of units to an existing NPP fleet, it is important to revisit the structure and organization of human resources for all of the activities identified above in order to ensure that decisions regarding the technology selected for the new unit fully consider the human resource impacts (and associated costs) for each alternative.

3.3. Site conditions

3.3.1. Number and design of the NPPs on site

Member States’ experiences have shown that more efficient staffing levels are available when an operating organization has more than one nuclear reactor unit or nuclear site location. Moreover, as the number of reactor units increases within the operating organization, the economies of scale appear to increase. This is possible due to the economies of scale available for many work functions, particularly in areas outside of operations and maintenance. Experience has also shown that many engineering activities can be centralized to support groups of reactors. Where possible, NPP operating organizations should also leverage support services from a parent organization including information management, budget/accounting, facilities maintenance, human resources, document control, inspections and testing, and training. Additionally, as the operating organization develops experience with power operations, best practices can be shared internally across the nuclear units to aid in continuous improvement efforts and realize additional efficiencies in the application of human resources.

Member States’ experience also shows that a single site location can support multiple NPPs with different Nuclear Steam Supply System (NSSS) technologies. Examples include E.On’s

Isar-1 and Isar-2 in Germany, PSEG Nuclear's Hope Creek and Salem in the United States and Olkiluoto-1, Olkiluoto-2, and Olkiluoto-3 in Finland. These examples include mixtures of PWRs and BWRs. In Finland, construction is underway on the Olkiluoto-3 unit. The commitment to build the PWR on a site with two existing BWRs indicates the operating organization's confidence that they can effectively and safely manage the operation of another technology at the same location (see Appendix II). These companies extensively share (or plan to share) almost all functions other than operations. Of course, within these organizations, there are sometimes divided groups who are dedicated to supporting one technology or the other. However, they apply all of their experience whenever possible to the common benefit of the NPP site.

3.3.2. Plant layout

The layout and location of major plant structures, infrastructure, and even plant components has a direct impact on staffing requirements. Carefully planning for proximity and ease of access can help optimise operations and maintenance personnel requirements. For an NPP site with more than one reactor unit, staffing efficiencies are increased for many work activities when there are common approaches to facilities:

- Common auxiliary building
- Common fuel handling building
- Common cooling water intake and outflow structures
- Cross-tied electrical systems, etc.

Site layout design also directly impacts security measures and the requirements for physical protection related to time, distance, and barriers. For lower security staffing, all support facilities should be located away from the vital area (or protected area) of the core NPP component structures (e.g. the administration building, the training facility, and the main warehouse).

Plant layout can also impact radiological characteristics. For example, when the radiologically controlled area is relatively small, the ability to remain distant from radioactive sources is diminished resulting in the potential for higher exposures. These kinds of conditions can result in additional staff to minimize individual exposure. The designers of advanced (generation III) designs have incorporated these considerations.

For maintenance personnel, staffing levels can be more optimised when the maintenance repair shops are closely located to one another, as well as having a close proximity to the turbine building/reactor building area.

3.3.3. Supporting infrastructure on-site

Current approaches to locating supporting infrastructure at the NPP site vary significantly. For some, operator training simulator facilities are centralized in one location in the country; while others have the simulator training facility co-located. Where they are co-located, they normally include additional training facilities for maintenance and radiation protection training activities.

Non-plant water treatment facilities may also be located off-site. The optimal condition is to connect the NPP site's water and sewer systems into existing local infrastructure to reduce the need for plant staff to operate and maintain an onsite water treatment facility.

3.3.4. Regulatory impacts

Positioning the NPP site relative to local geography may have a direct impact on personnel requirements due to various regulatory requirements. For example, cooling water outflows may increase local water temperatures beyond environmentally allowable levels without intermediate cooling efforts. This may apply for either salt water or fresh water cooling depending on a Member State's national, regional, or local regulations.

Additionally, emergency planning zones around the NPP site that encompass larger human populations and/or other industrial facilities can increase the personnel requirements for maintaining the regulatory planning and emergency response training requirements. The proximity to local fire departments and emergency medical facilities may also impact the personnel requirements to meet "first responder" timelines and capabilities.

The location of waste handling and storage facilities will also impact personnel and are directly impacted by national, regional, and local regulation. To the extent that these facilities are off-site, staffing requirements can be lowered.

3.3.5. Attractiveness of the community for potential employees

The positioning of the NPP site relative to social and cultural infrastructures may have a direct impact on the employees' cost of living, and their access to infrastructure such as available housing and public education. Typically, living costs increase significantly as proximity to desirable locations decreases. Offsetting this effect somewhat is that recruiting staff is generally easier in a desirable living area.

3.4. Plant design/implementation

3.4.1. Plant design/type

The optimisation of the number of plant personnel is one important objective for advanced plant designs. Passive and inherent safety features can contribute to the simplification of the plant design, and to a reduction in the number of systems and components, particularly safety grade systems and components. This, together with standardisation of components, serves to simplify maintenance and inspection by reducing the number of procedures, spare parts, and in some cases skills required.

Passive safety features can also substantially reduce requirements for operator actions following plant transients and design basis events. Modern man-machine interfaces can reduce the number of operating personnel. The systematic development of information management systems (i.e. the systems used to store, present, and manage all information in the plant) will also improve operability and maintainability of the plant. There are studies indicating that staffing reductions for the passive light water reactor plants compared to a current generation reference plant could be about 40 percent. A discussion of this information is available in IAEA-TECODC-1193 Staffing Requirements for Future Small and Medium Reactors (SMRs), Based on Operating Experience and Projections.

In case of passive light water reactor plants, it is of vital importance that plant personnel thoroughly understand the passive and inherent design features because plant safety relies mainly on these features. This also has to be taken into account in training programmes.

When a new NPP is constructed at an existing site, the ability to utilize the existing site infrastructure depends on the design differences between the new unit and existing units. If the design of the new NPP is close to the design of one or more existing NPPs on site, only operation shifts need to be dedicated for the new NPP. Other parts of the site organisation could be shared between several units. This reduces considerably the new plant staffing compared to locating the plant at a new site.

If the new NPP is of an advanced design, there are conflicting factors regarding the need for additional staffing. The volume of routine maintenance work may be less due to the smaller number of components compared to that of existing plant. On the other side, new design features may require additional technical support staff. These factors need to be evaluated by the organization, considering plant, organization and site-specific considerations.

3.4.2. Plant implementation model

In case of a first-of-kind plant, a turnkey (or close to turnkey) delivery or split package model may be considered. Also in the case of a turnkey delivery, the owner/operating organisation should be extensively involved during plant construction and commissioning. Persons involved in construction and commissioning will receive thorough on-the-job training and experience that will be invaluable during the operation phase of the plant.

It is of importance that the delivery of all necessary initial training and related training materials be included in the scope of vendor supply, where applicable. The Systematic Approach to Training (SAT) should be the basis for this training. See Nuclear Power Plant Personnel Training and its Evaluation: A Guidebook (IAEA Technical Reports Series No. 380). The analysis conducted should also identify appropriate continuing training programme content. The documentation needed for plant operation, maintenance and design updating needs to be included in the vendor's scope of supply. This documentation should be structured in such a way as to facilitate effective knowledge transfer and needs to be consistent with the documentation systems established for existing units. A plant-referenced, full scope control room simulator should be available in sufficient time for the training of the first operating crew prior to fuel loading. For first of a kind designs, meeting this goal has been a challenge. Part-task simulators have been used in some Member States to bridge this gap.

3.5. Plant operations and support

3.5.1. Extent of vendor support

The quantitative and qualitative characteristics of the staff required for operation and maintenance of an NPP is strongly influenced by the outsourcing strategy of the operating organization. Although the operations organization has traditionally been staffed by company personnel, there have been many cases where maintenance activities, and some technical support functions, have been performed through a contract with the vendor that supplied the plant systems and/or components. These conditions were due, at least partially, to the vendor having almost exclusive knowledge of the equipment, thus requiring the operating organization to rely on the vendor for technical and maintenance support.

This situation is gradually changing. First, the industrialization of NPP components and globalization of their procurement provides the operating organization with more choices. For example, the nuclear vendors in Japan and Korea have manufactured most major NPP components themselves, but no longer do so because of keen global-scale competition. Second, the ability to perform maintenance not only depends on the knowledge of the system and its components, but also on accumulated operation and inspection data, which is essential for preventive and proactive measures to avoid system and component problems. Since this data is usually stored and maintained by the operating organization (not by the vendor), the presence of the vendors in the maintenance field gradually decreases with the accumulation of experience. Based on these reasons, as well as costs, experienced operating organizations tend to conduct maintenance activities themselves rather than contracting with a vendor. The principal exception is for outage related work, where most operating organizations continue to rely on vendor support, particularly for specialized maintenance and inspections of major equipment.

This approach requires more skilled and knowledgeable operating organization staff, and thereby it strongly affects the organization’s resource-management strategy. For this reason, some organizations that have only a few units still prefer lump-sum maintenance contracts in order to avoid keeping extra staff. The level of involvement of the vendor in the maintenance field should be decided by taking staffing, performance and cost issues into consideration.

3.5.2. Engineering and technical support

Engineering and technical support approaches vary across Member States. In some Member States, all systems engineering and most technical and design engineering skills are retained in-house, and only rarely used skills such as metallurgy are supply by vendors. In other Member Sates, a few system engineers are part of the NPP staff, and all engineering and technical support services are provided by the component vendors. In this case, the operations and maintenance staff have more technical skills and provide many of the systems engineering functions as a collateral responsibility.

In either approach, a direct cost is incurred, and the NPP owner/operator must determine the value of each approach, and the acceptability of risk that may occur due to not having technical experts on-site on a regular basis. Additionally, in cases where operations and maintenance staff retain some of the technical skills, they become more difficult to replace and knowledge retention becomes more important.

A high level list of engineering and technical activities is provided below to highlight the large range of skills that must be retained in-house or procured through vendor support:

- Computer engineering (Plant process computers/simulators)
- Design/modifications engineering
  - Civil/structural, including seismic
  - Mechanical
  - Electrical
  - Instrumentation and controls
- Engineering programs

- In-Service inspections and testing
- Corrosion phenomena
- Probabilistic risk/safety analysis
- Equipment qualification
- Motor/air operated valves
- Fire protection

• Procurement engineering
• Reactor engineering/nuclear fuels analysis
• Systems engineering

In addition, daily technical support to plant operations must be available. To reduce plant trips and forced shutdowns, as well as enhance safety, personnel with the requisite skills and experience must be available to provide plant operators with rapid risk assessment and plant operability determinations.

Applying new technology will required adaptive planning, which means waiting for new technology to mature, be tested, and determine its applicability at the NPP. Historical examples include replacement of analogue control systems with digital equipment, control room habitability upgrades, implementing more computer based systems and computer-based training, the development of remote radiation monitoring equipment, and the development of remote testing such as thermography, sonography, and vibration analyses. Additional personnel beyond the base operating staff will be necessary to identify, test, and implement emerging technologies if an NPP owner/operator wishes to take advantage of their long-term benefits.

3.5.3. Outage management

Refueling and the management of outages normally require support from technical specialists not found on the NPP owner's staff. For example, for NPPs with steam generators, eddy current testing is required for lifecycle management. This testing requires specialists with specific equipment. Similarly, many NPPs retain small radiation protection technicians staffs and require additional support during major outages such as refueling. Some NPP operators choose to have in-house operations and maintenance staff qualified in this area while others hire external support companies with experienced technical staff.

In some Member States, NPP operators have almost all outage activities provided by an outside vendor (called "turnkey" services). Examples include refueling activities, eddy-current testing, chemical cleaning, inspection services, and maintenance activities. In these circumstances, sufficient technical expertise must be retained by the NPP operating organization to oversee and validate the work completed contractors.

3.5.4. Availability of contractors and consulting services

NPP operating organizations must also consider the availability of contractor and consulting services to support operations. Examples include maintenance, engineering and technical support, outage support, radiation protection, and administrative support. The range of outsourced services will be determined by (1) the availability of external skill sets and resources, (2) the cost of external services, (3) the ability of the NPP operator to hire and retain skills internally, and (4) the risk management philosophy of the NPP owner/operator.

As several large nuclear services companies have merged or been purchased in recent years, the nuclear services industry has become more global. Consequently, there are now major services companies from Europe, North America and Asia offering services on a worldwide basis. This current condition allows for smaller Member States with less nuclear infrastructure to more easily build, operate, and maintain a new NPP.

3.5.5. Multiple plant management

The practice of standardizing processes tends to reduce human resource requirements at existing fleets of NPPs. In the US, a recent survey of standardized practices at nuclear fleets identified ten commonly standardized areas which reduced personnel requirements:

(1) Corrective action programme
(2) Engineering design change process
(3) Information technology implementation
(4) Procedures (some)
(5) Organization structures
(6) Quality assurance programme
(7) Safety management
(8) Security
(9) Training
(10) Work control/work management

The approach an NPP owner/operator takes in making each of these ten areas common or standardized will be dependent upon local, regional, and national cultures, as well as the parent organization's culture. Some of these areas will also be influenced by requirements established by the regulator, including corrective action, quality assurance, security, and training. In some cases, organization structures may also be influenced by regulation, such as the quality program manager reporting independently to executive management.

The following text includes more detailed discussions of several areas that related to managing multiple NPPs that impact human resource requirements:

Procedures: The degree to which plant procedures are detailed and strictly followed should be considered. Some companies, with consent from their regulators, have less specific technical procedures and rely more heavily on the skills and qualifications of their technical staff. Others have more detailed procedures and require strict compliance and documentation of the execution of each procedure element. In the scenario where the next plant is different from the existing fleet, an NPP owner/operator may determine how this approach may change, depending on safety risk, as it might require more oversight and documentation review on one hand, or more training and certification on the other.

Quality assurance/management: As new units are added, there is no need to change the standard quality assurance programme. This provides an opportunity to realize economies of scale in management levels and to some extent in the inspection staff. If the new unit is in a different location, the quality management requirements will need to be identified and implemented. The quality assurance program will also likely oversee auditing vendors that support the NPP. This can lead to economies of scale if the new units are similar to those existing and, conversely, a possible need for increased human resources if the vendors are different.

Lifecycle management: The management of structures, systems and components (SSC) for the lifecycle of an NPP is very important and must be adequately managed. An advantage in optimizing human resources can be obtained when identical or similar SSC are used in adding new units since engineering resources become more efficiently applied. Additionally, with like SSC, economies of scale in the procurement of materials grow. NPP owner/operators will need to determine their philosophy on how to manage the lifecycles of the plant SSC. They will need to determine in what areas, if any, it runs equipment to failure, how extensively the preventive maintenance program is executed, when planned replacement will occur, and how to optimise the overall maintenance program (i.e. what are the acceptance limits for equipment performance).

Outage management: The NPP owner/operator will need to determine, both from a technical and cost standpoint, the operating cycle of the reactors. Once this is established, it will need to be determined whether in-house employees and/or vendors will perform outage activities such as refuelling, chemical cleaning, inspections, equipment maintenance, etc. Many one-unit reactor facilities conduct more work using internal staff due to their availability while the plant is shut down. At multi-unit reactor sites, activities supporting the other operating reactors need to continue, often resulting in the need for greater vendor support.

Operations shift structures: Operations personnel requirements are driven primarily by plant design and equipment complexity. However, human resource requirements can be impacted by the number of shifts that are applied. For example, a 5-shift rotation can be applied, but will required each shift to be "self-relieving" which means that each shift must be large enough to meet minimum technical specifications for crew size, and simultaneously meet minimum safety, fire protection, and emergency response requirements. In cases where these additional requirements become too burdensome, a sixth shift may be applied that is a dedicated relief crew. Either approach needs to include time for mandatory rest periods as well as training.

Additionally, the NPP owner/operator will also need to consider the alignment of other workers with the rotation of the operations crews. Other groups may also have rotating shifts, which may or may not be aligned with operations. These groups include security, radiation protection, and some maintenance functions. In cases where these groups are not on rotation with operations, considerations need to be given to off-hour support, such as evening and week-end coverage.

Provisions for on-call personnel: The requirements for on-call personnel are normally driven by regulation, and are related to the NPP's proximity to population areas. Regulations may also define the number of hours a person can work in a given period. Thus, there are conditions when an individual (or group) may not be allowed to be called in for crisis support, and a secondary layer will need to be identified. Thus, an integrated plan is needed for both technical and emergency response call-outs.

3.6. Stakeholder relations

Nuclear power plants have historically had opposition. Local, regional, and national entities may support or oppose the construction, operation, or early decommissioning of a given NPP. To explain the owner/operator's position to various stakeholder groups, the owner/operator may have to employ professional staff to manage these relations.

The organizational placement of these types of personnel is dependent upon the nature of issues at hand. Where the issues are geographically local to the NPP site, companies typically have the public communications personnel work on-site, and report directly to the NPP site management team. Where the issues are more regional, the personnel are typically in a parent organization, off-site from the NPP. Where the issues are national, the owner/operator may convey its desires through an industry-based organization, or employ an outside contractor who specializes in lobbying activities.

4. SUMMARY

This report addresses issues related to human resource management faced by Member States while expanding their nuclear power programmes. It will be helpful in optimizing human resources when expanding the nuclear power plant fleet. Key issues were identified that impact personnel requirements, ranging from reactor type/design, the national infrastructure and regulatory environment, to technical skill set requirements. Areas of particular importance were covered including government policies, training programmes, regulatory aspects, environmental assessment, life time management, workforce planning and national infrastructure.

APPENDICES I–VI

CASE STUDIES

Appendices I–VI provide case studies of human resource issues faced by NPP operating organizations, and how they were (or are being) addressed.

APPENDIX I

TVO/OLKILUOTO 3 – FINLAND

1. Introduction

Nuclear power plays a vital role in the electricity generation of Finland. It has covered about one fourth of the total consumption during resent years. There are two power companies owning nuclear power plants. Fortum Power and Heat (FPH) operates two WWER units, 488 MW(e) each, at the Loviisa site. Teollisuuden Voima Oy (TVO) has two BWR units, 840 MW(e) each, at the Olkiluoto site.

Several attempts have been made in Finland to start the construction of a fifth nuclear power plant unit since the operation of the two Loviisa units and two Olkiluoto units was commenced for about 25 years ago. An application was filed exactly before the Chernobyl accident took place in 1986, but it was cancelled rather soon. The next effort was undertaken in 1991. An application was submitted to the Government in May 1991 by Perusvoima Oy (PEVO), a joint venture owned by Imatran Voima Oy (IVO, now FPH) and TVO. Simultaneously, bid inquiries were sent to a number of European NPP vendors, and bids were received in October 1991. The project was cancelled, however, as the Finnish Parliament declined the application in September 1993.

2. Status of new plant construction in Finland

New studies on the fifth nuclear power plant were started in late 1990s [1]. They included among other things Environmental Impact Assessments for the Loviisa and Olkiluoto nuclear power plant sites and feasibility studies for various advanced light water reactor designs. Based on positive results, TVO submitted in November 2000 to the Finnish Government an application for a Decision In Principle (DIP) concerning the construction of additional nuclear power of about 1000–1600 MW(e) net capacity, to be located either at the Loviisa or Olkiluoto site.

According to the Finnish Nuclear Energy Act, a company considering a nuclear plant project must apply for a DIP from the Government on beforehand. The Government decides whether the project is in accordance with the overall good of the society. If the decision is positive, it needs ratification by the Parliament. Before the Government decision, various interested parties are heard, including the municipality of location and the Radiation and Nuclear Safety Authority (STUK).

The Government made in January 2002 a positive DIP based on TVO's application, and the Parliament ratified the DIP in May 2002 after thorough parliamentary handling.

Immediately after the Parliament ratification of the DIP, the finalisation of bid inquiry specifications (BIS) was commenced. The bid inquiries were sent out in September 2002 and the bids asked for March 2003. An intensive period of bid assessment started immediately after the submission of bids, accompanied by negotiations with the supplier candidates. A turnkey contract with the Framatome ANP — Siemens consortium (CFS) was signed in December 2003, implying the construction of a PWR of type EPR (European Pressurised Water Reactor) at the Olkiluoto site.

Until the construction stage, there was no line organization unit dedicated to the OL3 project. Work was done in projects established for specified tasks. Persons from TVO's line organization, mainly from the Engineering Department, were nominated to the project groups on part time bases.

During the stand by stage, there were several projects in TVO for the participation in the development of some advanced light water reactor designs [2–4].

In the beginning of the preparedness stage, all projects were gathered to a special programme, called "preparedness programme". The main goal of the programme was to increase readiness to make a decision on the next nuclear power plant project and create provisions for the prompt start of the decision in principle stage if so decided. The preparedness programme consists of the specific projects for the following topics:

- Environmental Impact Assessment (EIA)
- Site investigations
- General design criteria
- Feasibility studies for various plant designs
- Plant implementation model and schedule
- Licensing
- Communication.

The preparedness programme had a steering group consisting of the directors of TVO's various departments and a programme group consisting of the managers of the projects belonging to the programme. A detailed programme manual was maintained in order to govern all programme activities.

About 50 persons in TVO were nominated to the project groups of the preparedness programme. Many of them were as a member in several project groups. Only the programme coordinator, acting among other duties as a secretary of the steering group and the programme group, worked full-time for the programme. A similar organization and working model was applied successfully in an extensive modernization program of OL1 and OL2 late 1990s [5].

The OL3 project transferred to the decision in principle stage in November 2000 when TVO submitted an application for the DIP. That stage ended with the Parliament vote in May 2002. During the decision in principle stage, similar organization and working model was applied as in case of the preparedness stage. In addition to the activities directly connected with the licensing process, bid inquiry specifications (BIS) [6–7] were prepared and contacts kept with the vendor candidates. In this way, readiness was developed to submit bid invitations as soon as needed after a positive decision by the Parliament.

The bidding stage covered the time period from the delivery of the bid inquiries in September 2002 to the signing of the plant contract in December 2003. The tasks scheduled for this stage were the following:

- Preparation for bid evaluation
- Evaluation of bids
- Selection of site
- Contract negotiations
- Financing arrangements

- Planning of project implementation
- Preparation of construction license application
- Preparation of construction site activities.

In principle, the organization and working model was same as during the previous stages. However, the projects were adjusted to be in accordance with the tasks of the bidding stage. The activities during this period were regulated by a Procurement Manual that covered the work up to the signing of the plant contract.

The bid assessment organisation included about 100 persons, half of them working full day and half part-time. The evaluation team was divided in eight assessment groups, each responsible for its own discipline. The responsibilities corresponded to the different parts of the BIS.

In the beginning of 2003, TVO's line organization was adjusted to cope better the new situation (Fig. 2). The goal was to separate OL3 activities and OL1/OL2 activities so that they do not disturb each other.

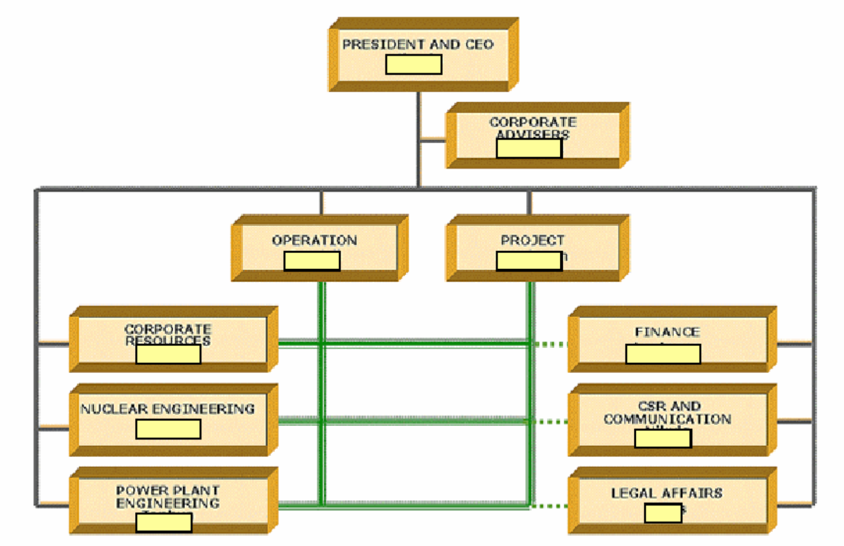


Fig. 2 TVO's organization.

A new department, a project department, was established for the OL3 tasks. The operation department concentrates only to the OL1/OL2 operation and will later prepare, in addition, for the operation tasks of OL3. The nuclear engineering department, the power plant engineering department and the Corporate Resources Department as well as other supporting organization units are serving both, the OL3 project and the OL1/OL2 operation.

The main duties of the project department are to

- watch over the implementation of CFS's scope of supply,
- conduct licensing activities,
- implement works related to site preparation and infrastructure,
- make preparations for the operation stage and
- arrange the training of the OL3 staff.

The project department consists of the organization units for project services, nuclear safety, quality management, risk management, plant engineering, civil construction and procurement. The project tasks have been divided into subprojects that are normally leaded by a person from the project department. The subproject groups consist of persons from the project department and TVO's other departments.

4. Recruitment

The staffing of the project department is based on three main sources: recruitments from the outside of TVO, transfers from TVO's other departments and leasings from consulting companies. In the beginning of 2005, the size of the project department was about 120 persons. The number is estimated to grow with some tens until the installation stage.

TVO employees in the project department will be transferred to other departments after the OL3 construction is finished. The expiration dates of the leasing contracts regarding the persons from consulting companies are adjusted in the accordance with the need of those persons. The recruitment of the control room personnel will be carried out in 2005. Some of them will come from TVO's current operation staff. The total TVO staff after the OL3 commissioning is estimated to be about 150 persons more than before the start of the OL3 project.

The bright political climate regarding the future of nuclear power in Finland has helped TVO in recruiting new staff. An example is that almost 1000 candidates replied to TVO's recruitment request some months after the Parliament vote on the DIP in 2002. In general, TVO has not experienced any major problems to recruit new staff. The only problem area has been I&C engineering.

5. Training and education

There are two technical universities in Finland giving basic education in nuclear engineering; Helsinki University of Technology and Lappeenranta University of Technology. For assuring the adequate supply of young engineers, TVO has maintained close relations to those universities. TVO has continuously several students preparing thesis required for a diploma. After graduation, many of them have continued at TVO as permanent employees.

The interest among students to start nuclear studies has been modest but sufficient in 1990's. The OL3 project has made the nuclear engineering more attractive.

A national post-graduate training course on nuclear engineering and safety was arranged in cooperation with utilities, authorities, research organizations and universities in 2003 for 50 attendees from those organizations. The course was repeated with the same amount of attendees in 2004 and 2005. Several special courses on nuclear standards and safety requirements have been also arranged for persons from manufacturing industry.

The CFS scope of supply includes the delivery of a full scope training simulator for OL3. It is due to be ready before the end of 2007. It means that the control room personnel can be trained with that simulator in good time before the OL3 commissioning. The CFS scope of supply includes also all plant specific training material as well as training of TVO's personnel.

6. Workforce planning

Due to the company history, the age profile of the TVO staff has been peaked to the age of 50–60 years. It means a drastic generation change in coming 5–10 years. The OL3 project is assisting TVO to cope with that issue. Young persons have been recruited to the OL3 project tasks. They are supported by senior experts from TVO's other departments. After the construction project is over, young experts will be able to succeed retiring senior experts. The need of the OL3 project staff and the number of the seniors reaching the retirement age in TVO will match quite well in time.

TVO has defined key competencies for the entire company and for each organization unit. A computerized system includes information on competence requirements and actual competencies of each employee. This system is utilized for creation of training programs. TVO has also in use a simple Excel-based system for succession planning. It tells when successors have to be employed for the key experts taking into account the time needed for training and knowledge transfer.

The transfer of tacit knowledge is a challenge. In order to find an effective and systematic procedure TVO is supporting some university studies in that area. TVO has also conducted pilot projects regarding mentorship and senior-junior knowledge transfer methods.

7. Conclusion

New plant construction has been stopped for a long time in western countries. Technical experts being involved in plant construction have retired or are approaching that age. There is a risk that valuable knowledge can disappear from the involved organisations with the retiring people. Simultaneously, there can be difficulties in hiring talented people to succeed them. Nuclear technology has not been any more as attractive among students as it was a few decades ago. Nuclear technology departments in many universities and research centres have ceased their activities. Nuclear phase-out decisions in some countries have contributed to this kind of a negative trend.

One of TVO's policies to cope above issues and to maintain and enhance the expertise of its own staff has been to have challenging projects always in progress. Those projects force to keep expertise up-to-date. They also enhance the motivation and alertness of the staff by giving interesting working tasks. The most important projects since the commissioning of the plant units have been the modernization of the existing plant units, the participation in the development of some advanced light water reactor designs, and the study programs for a new nuclear power plant unit.

The last mentioned activity has been long lasting, started already in early 1980's. Finally, this effort resulted in the investment decision in December 2003 and the start of the OL3 project. TVO is confident that the staffing and training needed for the new plant unit can be arranged in a proper way. The OL3 project is also assisting to cope with the internal expertise issue facing by TVO due to the nearing generation change.

REFERENCES

[1] RASTAS, A., “Extension of Nuclear Capacity: a Finnish Energy Solution in Harmony with Environment, Climate and Economics”, World Energy Congress (WEC ‘04), Sydney, Australia, September 6–9, 2004.

[2] RAO, A., YADIGAROGLU, G., RASTAS, A., ARNOLD, H., GONZALES, A., “Simplification of Plants Using Passive Features. The ESBWR Approach, TOPSAFE ’98, Valencia, Spain, May 15–17, 1998.

[3] HAUKELAND, S., IVUNG, B. and PEDERSEN, T., (ABB Atom) Sweden, Ami Rastas (Teollisuuden Voima Oy) Finland,” BWR 90+: The Next Generation ABB Atom Advanced BWR”, ENC’98, Nice, October 25–28, 1998.

[4] RASTAS, A., “International Cooperation”, International Conference, SWR 1000, A Reactor Concept for the Future, Hotel Maritim Königswinter, Germany, November 5, 1998.

[5] RASTAS, A.J., “Additional Competitiveness and Safety by Modernization at Olkiluoto”, European Nuclear Conference “Nuclear Power Generation Safe and Competitive – Now and in Future” (ENC 2002), Lille, France, October 7–9 (2002).

[6] PATRAKKA, E., “Compiling Utility Requirements for New Nuclear Power Plant Project”, Proceedings of ICAPP’02, Hollywood, Florida, USA (2002)

[7] PATRAKKA, E., “Contract Specifications For Olkiluoto 3 Nuclear Power Plant”, ICAPP’04, Pittsburgh, PA, USA, June 13–17 (2004).

APPENDIX II

ADDING PBMRs TO A PWR SITE (ESKOM) — SOUTH AFRICA

1. Introduction

ESKOM Holding Limited, the South African Government owned utility, operates over 10 power stations. The total installed capacity is about 40 GW, and nuclear contributes only 6 percent.

The existing nuclear power station, Koeberg NPP, is comprised of two 900 MW(e) units at the South African west coast near Cape Town. The Koeberg NPP units are Framatome PWR designs.

The South African government has a policy to increase the share of nuclear in the generation mix from 6 percent to 15 percent before 2020. In this regard, the government has approved the design and demonstration of the pebble bed modular reactor (PBMR). The PBMR is a high temperature helium cooled reactor design with a direct cycle. The thermal rating of the reactor is 400 MW(e) with the electrical output of 165 MW(e).

The key characteristics of the PBMR design are:

- inherent safety,
- load following,
- modularity and
- simple systems.

2. PBMR development status

The initial project activities involved the transfer of technology from HTR GmbH (ABB and Siemens). The technology for both the power plant and the fuel plant was contained in documents and experience that was vested in individuals.

There were many other concurrent activities with the technology transfer. These involved the design of the power and fuel plants, licensing, environmental impact assessment (EIA), and applications for other authorizations.

Key milestones

EIA record of decision is expected:	July 2006
Construction nuclear license:	Dec 2006
Construction start:	Nov 2007
Cold commissioning:	Dec 2009

The contracting for all the key long-lead items has been completed with the suppliers. Work is proceeding apace and within schedule.

3. Staffing and organization

PBMR (Pty) Ltd, the vendor organization, requires its own staff to perform the design, project management, quality assurance, and licensing of both the power and fuel plants. The total staff requirement is about 1000 people including support staff in finance, HR, IT, etc. There will be additional part-time personnel that will be part of the organization during construction activities.

ESKOM, as the envisaged owner operator of the PBMR demonstration plant, will supply the approximately 100 power station staff. These will range from O&M staff to the technical support staff such as system and fuel engineering and outage management.

The training of operators and other engineering and physics personnel is being undertaken in advance of plant construction.

Due to PBMR and Koeberg sharing a site, it is expected that the two power stations will share non-technical support staff and other supporting facilities. It is, however, not expected that the engineering personnel will be shared as the two technologies are rather different.

4. Recruitment, training and education

The recruitment process has initially involved the transfer of personnel from ESKOM, the South African Nuclear Energy Corporation (NECSA) as well as direct recruitment from the market. The primary recruitment process, going forward, will be from universities and other Further Education Training (FET) institutions with a focus on ESKOM and PBMR (Pty) Ltd providing the specific nuclear training. In this regard, both ESKOM and PBMR provide bursaries, project work and other assistance to selected candidates. Upon completion of studies, the specific training is provided both in-house and with partner national and international organizations such as suppliers.

5. Conclusion

Internationally, there has been a “greying” of nuclear experts and a shrinking of nuclear engineering and science departments. As a consequence of this, ESKOM has realized that a large number of young engineers and scientists would have to be recruited and then trained in South Africa and abroad.

The South African government in partnership with ESKOM, NECSA, and PBMR (Pty) Ltd has started a process of funding university chairs in reactor engineering and allied subjects. These departments undertake research and provide training for the South African nuclear industry. The primary initial focus of this program will be on High Temperature Reactors.

The output is very much biased forward in support of PBMR demonstration reactor development, construction, and commissioning.

APPENDIX III

CERNAVODA NUCLEAR POWER PLANT: PHASED IMPLEMENTATION OF SIMILAR UNITS — HUMAN RESOURCE MANAGEMENT AND TRAINING PROGRAMMES (ROMANIA)

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 MW(e), designed by Atomic Energy of Canada Ltd (AECL). Provides about 10 percent of the total country energy consumption. 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".

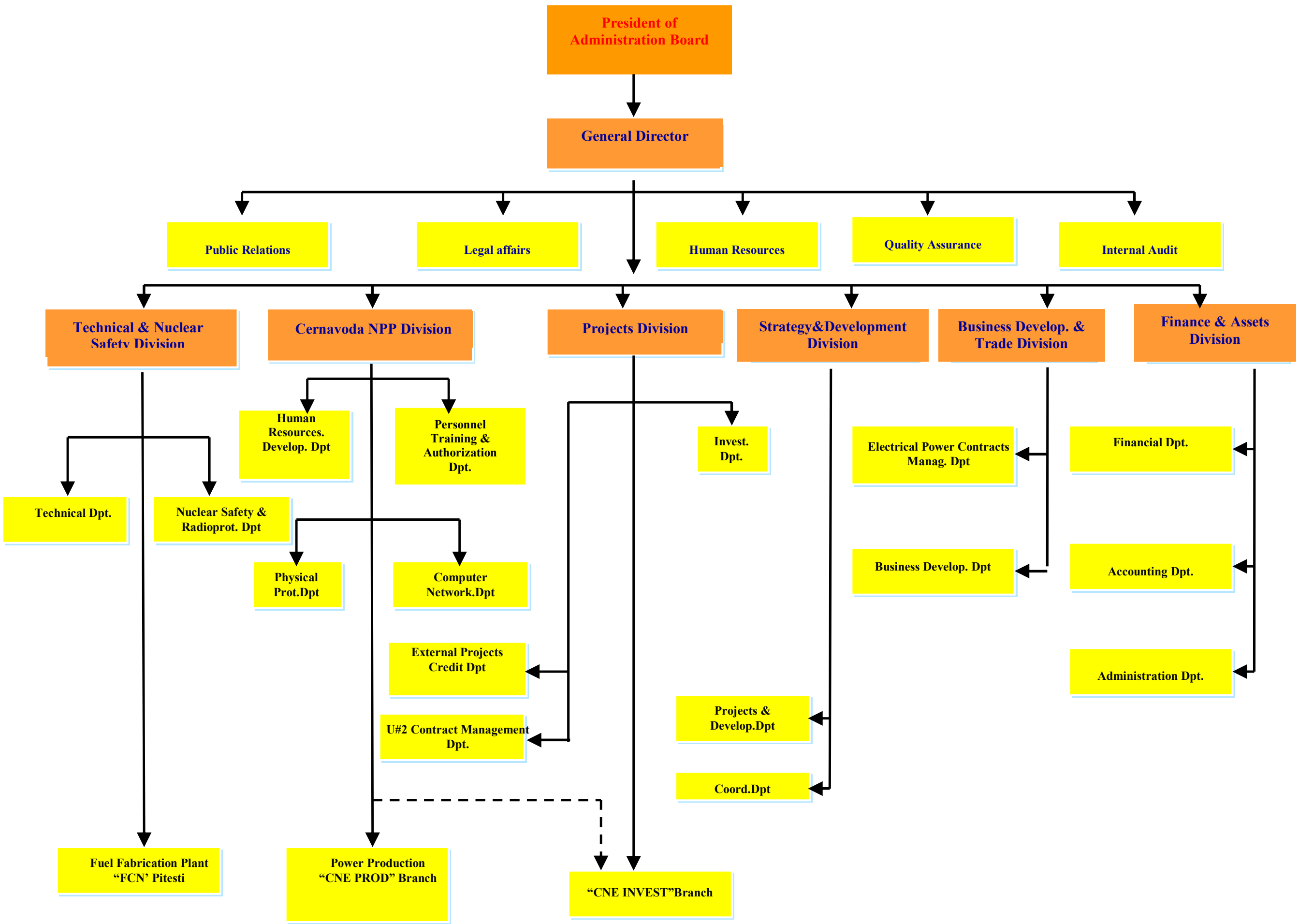
The plant was designed to have five similar units. The studies performed for the plant, prior to the construction's start, established feasible technical solutions for all problems related to a 5-unit site, including the environmental impact, which would be entirely acceptable. Construction of the first unit started in 1980 and of 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 with 1990, the work on Cernavoda site was focused on Unit 1 and the construction at the other units was suspended. Since then, only preservation activities have been carried-out.

The re-start of work at Unit 2 took place in 1995, under the management of the AECL-ANSALDO Consortium. Some construction work was carried-out (e.g. installation of the fuel channels) and a thorough assessment was performed concerning 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 advance in the construction of Unit 2.

Since then, many economic estimates foresee that, starting with winter 2005 when Romanian electricity consumption is expected to increase with about 1000 MW(e), the annual electricity production will become insufficient and will be not covered 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 a great support for the completion of Cernavoda Unit 2.

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 is expected to be operational in 2007.

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



SNN S.A. Organization chart.

Staffing and organization

Since July 27, 1998, Societatea Nationala "Nuclearelectrica" (SNN) S.A. is reporting to the Ministry of Economy and Commerce and the state owns 100 percent 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 the Cernavoda NPP Unit 1 in a competitive, safe and environmental friendly manner so that the production be optimised and the economic life time of the plant be as long as possible. 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. SNN S.A. has three branches:

(1) "CNE PROD", operating the Cernavoda NPP Unit 1 and auxiliary services.
(2) "CNE INVEST", including Units 2 to 5, actually in charge with the Unit 2 completion and U3 – U5 preservation.
(3) "FCN Pitesti", the Nuclear Fuel Plant, qualified manufacturer for CANDU 6 type nuclear fuel that fully covers the needs for the Cernavoda NPP operation.

Also, at the level of SNN S.A. headquarters, there are six main divisions:

(1) Technical and Nuclear Safety
(2) Cernavoda NPP
(3) Projects
(4) Strategy & Development
(5) Business Development & Trade
(6) Finance and Assets

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 are AECL experts from Canada, 80 ANSALDO employees from Italy and 700 are "Nuclearelectrica" permanent employees. A similar organization was applied successfully for the Unit 1 Project.

The main activities related to Unit 2 commissioning and initial operation are focused on system commissioning, preparation of commissioning procedures and commissioning reports (e.g. Commissioning Completion Assurance Reports), preparation of operating documentation, and assessment of documents (such as history documents).

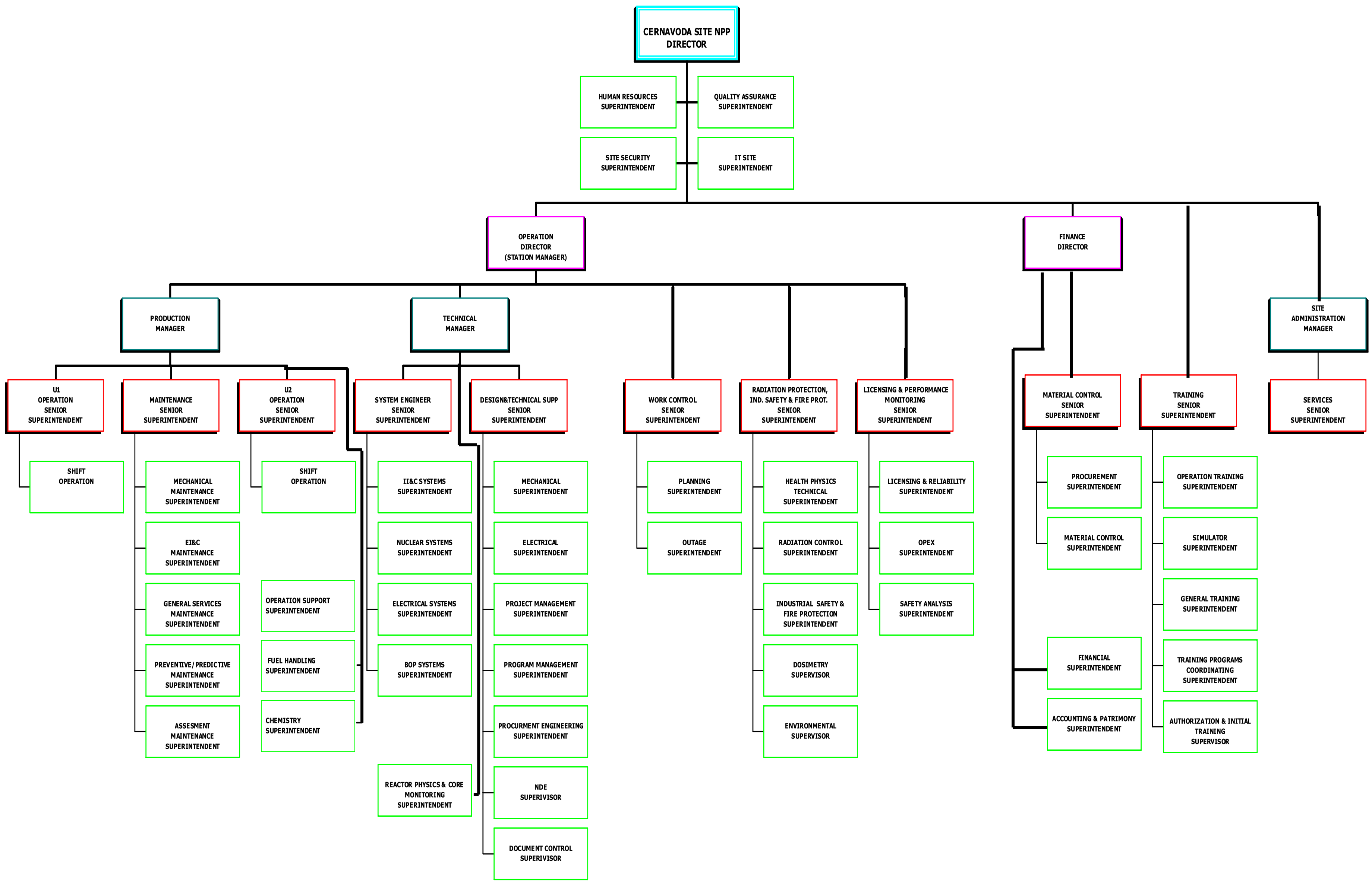
Main phases for two unit integration

After the turnover of Unit 2 from the management team to "Nuclearelectrica", in 2007, the U2 operation will be integrated into a "Two-Units" organization (together with Unit 1). Unit 2 integration will be carried-out gradually, starting from the construction stage and ending with commercial operation in 2007.

The first step was the development of "Two-Unit" Organization Chart taking into account experience gained from Unit 1 and from similar plant operation, in order to avoid parallel activities and duplicative responsibilities. Thus, Unit 1 and Unit 2 will share a part of existing staff of Unit 1 (technical services personnel, training personnel etc.) and many of the common station services. Only operation personnel and a few groups of maintainers, chemical technicians and fuel handling operators will be special dedicated for Unit 2 operation.

Then, the next step was to hire staff to fill the new positions, according to identified needs. The new employees received general training and were assigned to Unit 1 departments to receive on-the-job training, according to defined job requirements and qualification. Together with a number of experienced staff from Unit 1 they were transferred to the Management Team, at different stages, to carryout the commissioning and initial operation activities. After the turnover of Unit 2 from the Management Team to SNN S.A., they will be assigned to their positions on the Two-Unit Organization Chart.

CERNAVODA NPP U1 + U2 ORGANIZATION CHART



Recruitment

The Unit 2 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 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, systems 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 assignment to the Point Lepreau station in Canada during 1992 and 1993.

Control room operators and shift supervisors have been recruited from Unit 1 operations staff. Also, a number of non-licensed operation positions were filled with experienced nuclear operators from Unit 1.

Training and education

According to Cernavoda NPP training policy, Unit 2 staff shall be qualified for the tasks they are asked 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 activities for Unit 2 personnel address the essential capabilities and qualifications to support plant commissioning and operations. Training needs for Unit 2 personnel have been identified based on Table Top Analysis performed for similar jobs from Unit 1 of Cernavoda NPP.

Training programme implementation started in 2002, with first 250 persons hired for commissioning and operation. Until now, for commissioning and operation of Unit 2, about 350 persons are being trained within the Cernavoda NPP Training Department and Unit 1 facilities. Also, Unit 2 personnel training programmes involved lecturers from “Ovidius” University Constanta and the Bucharest Polytechnic University.

Initial training

Initial training for Unit 2 personnel contains 2 main parts:

- General technical nuclear training programme
- On-the-job training programme

The general technical nuclear training programme consists of 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 program, the requirements for radiation protection and actions in the event of a 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 further understanding of the principles of station systems and equipment operation.
- *Plant systems training* — provides a technical understanding of the plant major systems in both the nuclear and the conventional areas.

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

- Specific knowledge and skill for a particular job
- Familiarization with reference documents, station instructions and work procedures that refer to a particular job

In order to meet the licensing requirements, experienced and qualified staff from Unit 1 fill the Control Room Operator and Shift Supervisor positions for Unit 2. Five Unit 1 Licensed Shift Supervisors and 12 Control Room Operators started the Initial Authorization Training Programme to obtain Unit 2 operating license.

The training programme has been focused on:

- System specific training on design differences between Unit 1 and Unit 2.
- 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.
- Practical training related to Unit 2 Control Room panel configuration, system tests 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 elemental systems knowledge. A main part of the on-the-job training programme has been carried-out in 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.

The Unit 1 simulator is used for Unit 2 operator simulator training and also for examination by the regulatory body.

Continuing training

The purpose of Unit 2 Continuing Training Programme is to maintain and improve employee's job performance and to develop their 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

APPENDIX IV

KHNP STAFFING PLAN OF CONSTRUCTION SITE OFFICE: ULCHIN 5&6 CONSTRUCTION PROJECT (REPUBLIC OF KOREA)

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 appendix presents a staffing plan for the field construction office from starting initial project implementation to final turnover to operations. 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.

General discussion

The proposed staffing plan is for an NPP construction project with two PWR units of 1 000 MW(e) 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.

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 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 to 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

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. Manpower on other activities may be shifted to keep the level close to the same total crew sizes.

Initial staffing in key position will be filled with experienced personnel from existing plant 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 for the project.

Although the chronological manloading of the field organization personnel for accomplishing 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 include 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 residents 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.

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). A 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, construction support section, and 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.

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 increases, 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: Startup/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.

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 V

HOW TO RETAIN NUCLEAR POWER PLANT STAFF WHEN DELAYS OCCUR DURING CONSTRUCTION (ARGENTINA'S EXPERIENCE WITH THE ATUCHA AND EMBALSE NPPs)

Introduction

It is common, especially, during the construction stage of the first NPP, to have some delays due to different causes (main components manufacturing, relevant field interferences, engineering modifications, etc). The first and second NPPs are typically contracted under the "turnkey" modality. The training of the operating staff is also considered in the contract. Important milestones are established, including recruitment period, position profiles and minimal qualifications. The dates and duration of training overseas (main supplier's country) and inland are specified. The training duration and date of staff return to the site become relevant.

If the owner and the main contractor do not adequately monitor the recruitment and training process, in case of construction delays, the site will start receiving a trained team too early that has no specific tasks assigned during the construction stage. Boredom may start in the members of this team. Depending upon the employment market or other industries' attraction, the integrity of a well-trained group may deteriorate.

In case of resignations, it would be a tremendous effort for the owner to recruit, train and motivate a new staff. Sometimes, licensing on time may jeopardize the start-up milestone. This case study describes how retaining and motivation programmes were applied in order not to lose the previously trained personnel at the Atucha 1 and Embalse NPPs (Argentina).

The first NPP – Atucha 1

Atucha 1 is a 335 MW(e) net capacity, PHWR (Pressure Vessel Type). The NPP was a turnkey contract between National Atomic Energy Commission, Argentina and Siemens A.G., Germany. Construction started on June 1, 1968, and first criticality was achieved on January 13, 1974. Commercial operation was declared on June 24, 1974. It was the first NPP in Argentina and the first NPP exported by Germany.

In accordance with the contract, part of the staff was trained by the supplier, in Germany and part trained in Argentina by the owner. A delay of 1.5–1.8 years occurred during construction due to additional assessments to be performed under the pressure vessel cladding and fuel element vibration detected during cold testing. In order to retain the operating personnel, the following actions were taken:

- Postponing the return of part of the staff under training in Germany (extending training at the German NPPs).
- Extending the training for the staff returning to the job site.
- Integrating the returning staff and the already trained staff on site and completing the following activities:
  - Familiarization with systems and components (walk downs and inspections).
  - Participation in procurement activities (instruments, spare parts and consumables).
  - Participation in tests and commissioning.

With the above described measures, resignations were negligible.

The second NPP – Embalse

Embalse is a 600 MW(e) net capacity, PHWR with pressure tubes of the Candu type. The NPP was a turn-key contract between National Atomic Energy Commission, Argentina and Atomic Energy of Canada and Italimpianti, Italy. Construction start on April 1, 1974. First criticality was achieved on March 13, 1983, and commercial operation declared on January 20, 1984.

The owner's target for the second NPP included:

- Increased local participation.
- Developing and qualifying local suppliers.
- Detailed engineering performed locally.
- Erection performed by local subcontractors.
- Acquiring construction knowledge.

Taking into account that the original construction time was too optimistic and the above targets also involved delays, the total delay was 2 to 3 years. These delays were due to:

- Development and qualification of local suppliers.
- Detailed engineering found many interferences (general arrangement drawings supplied by the main contractor had not taken into consideration such situation).
- Awarding delays to local construction/erection subcontractors.
- Procurement delays (manufacturing and delivery).

In facing such problems, the owner agreed with the main contractor to have a larger national participation during construction. A special construction owner's group was created. Such arrangement allowed:

- Increasing the owner's knowledge regarding construction, non-destructive testing and detailed engineering.
- Reducing construction time.

The operating team, part in Canada and Italy and part on site, were re-programmed according to the following strategy:

Team in Canada:

- Specialists in software and hardware of the main computers to remain in Canada an additional year.
- Specialists in fuel handling and physics to extend their training in Canada one year.
- Remaining staff to return to site and participate in construction/inspection and to become familiar with systems already installed, to plan testing and be prepared for commissioning.

Team in Italy:

- To return to the site, where turboset and Balance-of-Plant activities were well advanced, and to be involved in inspection and testing activities.

Team originally on site:

- To receive additional training from staff returning from Canada and Italy.
- To participate in construction/inspection activities.

Conclusions

With the described strategies, nobody felt frustrated or bored on site, even during the last stages of construction. The management target was to keep the operating personnel always motivated and busy by participating in the construction progress, inspection and testing. Regarding the personnel who had to be examined and licensed, it was very important to determine the date when they had to be separated from the construction/inspection team in order to be assigned to the refreshment and retraining activities.

APPENDIX VI

RETENTION OF KOZLODUY NPP EXPERIENCED PERSONNEL FOR A NEW NPP IN BULGARIA

1. Background

Kozloduy Nuclear Power Plant (KNPP) plc is a state-owned company that operates six units with total capacity of 3 760 MW(e). All units are pressurized water reactors of Russian design. Unit 1 was commissioned in 1974.

On 31st of December 2002, KNPP units 1 & 2 were shut down following a decision of the Bulgarian Council of Ministers and are in the first stage of the decommissioning.

In compliance with the Accession Agreement to the European Union the Bulgarian government has committed to close units 3 & 4 by the end of 2006.

At the moment, Kozloduy NPP generates 40% of the electricity in Bulgaria. In order to maintain acceptable sale prices the National Electric Company (NEC) buys the power generated at a low, state-regulated price. The closure of KNPP units 3 & 4 will increase the electricity price in Bulgaria.

Additionally, Bulgaria covers more than 40% of the power shortfall in neighbouring Balkan countries — Serbia, Macedonia, Albania, and Greece. After shutting down units 3 & 4, Bulgaria will only be able to satisfy its own needs, thus resulting in a power shortfall in the Balkan region.

Bulgaria has a clear policy on development of nuclear power production. It is aimed at sustaining the nuclear share in the structure of the power generation of the country. In 2003 the Bulgarian government adopted a decision to recommence the construction of the second nuclear power plant — the Belene NPP that was frozen in 1991.

NEC manages the Belene NPP project. The US Company Parsons has been chosen to be the architect-engineer for the Belene project and in March, 2006 the bids for the construction of the Belene NPP are scheduled to be submitted. According to the governmental plan the Belene NPP is to be commissioned in 2011.

2. Need to retain qualified personnel

The decision of the Bulgarian government to close some KNPP units and to commission the Belene NPP unambiguously determines the necessity for retention of experienced personnel. However, there is a gap of 9 years between the closure of units 3&4 and the commissioning of the new NPP.

KNPP management is responding to this challenge and has undertaken a number of measures to retain qualified personnel. The decision and the measures undertaken to retain KNPP personnel are the basis of the infrastructure necessary to develop further the nuclear industry in Bulgaria.

3. Measures for retaining the qualified personnel

3.1. Optimizing the number of personnel

When units 1 & 2 were closed in 2002, KNPP had 5 300 personnel. 70% of them worked in the operation, maintenance and the engineering organization of KNPP units. The other 30% were involved in the accountancy, administration, and other supplementary activities and their skills are not specific to the operation of a nuclear power plant.

According to Bulgarian law the State controls the sale price of KNPP electricity, as well as salaries. The personnel numbers are not controlled and depend on the plant's management. In order to retain qualified and experienced personnel after units 1 & 2 closure, measures were taken to optimize personnel numbers.

For personnel number optimization two main measures were applied:

- outsourcing;
- encouragement of early retirement.

Since 2001 several auxiliary activities, such as catering canteens, landscaping, cleaning, and transport services, have been contracted to external companies.

KNPP management agreed with the Trade Unions' financial incentives on voluntarily early retirement (the average retirement age is 60 years old). These incentives are aimed mainly at less qualified personnel, who are more easily replaced. After introduction of this measure about 150 people retire annually, compared to 10–15 before that. Simultaneously, analyses of vacancies were performed, and through work redistribution, the personnel number was reduced.

These measures resulted in reduction of personnel to 4 900 at the end of 2005. At the same time key qualified personnel have been retained. Furthermore, various positions within the plant became vacant which encouraged personnel to change positions.

3.2. Redeployment of personnel from the closed units

After closure in 2002, units 1 & 2 have a zero power operation license — nuclear fuel is stored in the spent fuel storage pools near the reactor vessels. Due to the specific features of unit 1 & 2's design, the licence requires that the primary circuit, and a part of the secondary circuit, be maintained to ensure safe storage of the fuel. This requires both operational and maintenance personnel to be retained, though reduced in numbers.

In 2003 new requirements regarding the number of the personnel dealing with the maintenance of units 1 & 2 have been introduced. They will be applied until the fuel from the spent fuel storage pools is removed. Thus, a 10% reduction of personnel employed on VVER-440 units 1–4 has been achieved.

As a result of the early retirement policy implementation, there was no need to redeploy maintenance personnel. The reduction in numbers due to a reduced scope of activities was achieved through early retirement and work redistribution amongst the remaining personnel. Overall, two groups of personnel were redeployed to different positions:

- Operational personnel from the main control room, and
- Field operators (working on secondary circuit, electric systems and I&C).

Employees' aspirations were determined after discussions with their line managers. Although the employees had a chance to leave the company, they decided to stay and have successfully undergone training for new positions.

KNPP experience to redeploy specialists demonstrated two main approaches to retain the qualified personnel and their training for new duties, which can be used for the forthcoming commissioning of Belene NPP:

- Maintaining personnel motivation through taking new responsibilities, and
- Encouraging individual development of personnel.

3.3. Maintaining personnel motivation

In 2004 a project began for development of a system for assessing and maintaining personnel motivation. The project, financed by the UK DTI Nuclear Safety Programme, was implemented in cooperation with British Nuclear Group and was finalised at end of 2005.

During this project a questionnaire was developed to assess personnel motivation. A representative sample of KNPP personnel were interviewed through Employee Survey 2005. The questionnaire assessed the motivational factors in the organisation and will be applied periodically at KNPP to assess progress. KNPP key personnel were trained to carry out follow up assessments on their own.

The results of Employee Survey 2005 were favourable in relation to retention of the qualified personnel. Future employment in Belene NPP was indicated as a main reason for continuous to work in the nuclear field. Also, the possibility to work on international projects was a positive motivation.

Based on the results of Employee Survey 2005, a Corrective Action Plan has been developed and implemented. It covers 5 major areas:

- Human resources management;
- Internal communications;
- Control of documentation;
- Positive attitude towards safety;
- Leadership training.

The implementation plan is being implemented under the supervision of senior management.

3.4. Encouraging the individual development of staff

In addition to the training system, opportunities for qualification improvement and individual development of personnel have been established in KNPP:

- University education is encouraged for areas applicable to KNPP.
- English language training is conducted.
- Training for additional qualification of engineering personnel is conducted.

In order to retain qualified personnel, training expenses are covered by the KNPP and a training contract is signed with the trainees. Thus, the newly trained personnel should continue to work for the plant for a specified period of time (usually one to three years). In case the trainee unilaterally terminates the contract the person pays a certain sum covering the expenses incurred, as well as some penalties.

An individual performance appraisal is carried once a year. As a result of the appraisal, measures are taken to improve performance, usually in the form of additional training. The assessment methodology provides the opportunity for the line managers to identify the employees that have a potential for further development.

The development of an individual's potential depends on their personal decision and initiative. Thus, the Corrective Action Plan foresees formalisation of the process of aspirational counselling on the individual's future aspirations. An instruction was developed that foresees counselling in case of organisational change, as well as the case when the individual is not able to continue work in the same position for health or other reasons. In addition, line managers have an opportunity to initiate counselling for their workers.

Expectations are that with such an approach, which is used by some nuclear operators around the world, KNPP shall be able to plan for changes in the work force at an earlier stage.

3.5. Other methods for retaining the personnel

KNPP personnel have additional social benefit, which are still not applicable in the other Bulgarian companies. For example every employee has a private pension scheme, which provides an additional 20% from the lowest pension in the country. More than that, personnel use private health insurance, which ensures medical care of the highest quality. The health and pension expenses are covered by KNPP, which leads to some tax relief.

Since 2002 some additional possibilities for voluntary pension schemes have been introduced, as well as health insurance for family members up to 26 years old. These possibilities are negotiated against shorter annual paid leave. Now the paid annual leave in KNPP is about 40 days per year, which creates the necessity for a greater number of workers. These possibilities have proven to be attractive for young specialists because of the health insurance for family members, and for other specialists because of the chance for additional pension.

4. Conclusions

KNPP faces a challenge to keep its qualified personnel for several years (regardless of the units' closure), so that in a certain period of time these experts may be transferred to the Belene NPP. That is the reason KNPP management has undertaken additional financial obligations maintaining higher personnel numbers. Expenses for retaining existing personnel are comparable with the future expenses for training of completely new personnel.

Retaining qualified personnel is not only a financial challenge. Re-qualification from nuclear power production to another area does not need much funding or time. In a situation where there is a free labour market for qualified experts, the decision to keep one's position in the area of nuclear industry becomes ever more personal. The role of the operating organisation is to establish conditions to motivate the personnel to remain and develop in the nuclear field.

Three years after the closure of units 1 & 2, KNPP managed to retain qualified personnel and the additional measures undertaken will enable them to face the new challenge — completing and operating Belene NPP.

GLOSSARY

Advanced design is an NPP design of current interest for which improvement over its predecessors and/or existing designs is expected. Advanced designs are further divided into evolutionary designs and innovative designs.

Evolutionary design is an advanced design that achieves improvements over existing designs through small to moderate modifications, with a strong emphasis on maintaining a proven design to minimize technological risks. The development of an evolutionary design requires at most engineering and confirmatory testing.

Innovative design is an advanced design that incorporates radical conceptual changes in design approaches or system configuration in comparison with existing practice. Substantial R&D, feasibility tests, and a prototype or demonstration plant are probably required.

Passive safety features are structures, systems, and components that actuate to cool and protect the reactor core under design accident conditions without operator action.

IAEA PUBLICATIONS RELATED TO HUMAN RESOURCE MANAGEMENT FOR NUCLEAR POWER PLANT OPERATING ORGANIZATIONS

Manpower Development for Nuclear Power: A Guidebook, Technical Reports Series No. 200 (1980).

Nuclear Power Plant Personnel Training and its Evaluation: A Guidebook, Technical Reports Series No. 380 (1996).

Nuclear Power Plant Organization and Staffing for Improved Performance: Lessons Learned IAEA-TECDOC-1052 (1998).

A Systematic Approach to Human Performance Improvement in Nuclear Power Plants: Training Solutions, IAEA-TECDOC-1204 (2001).

Nuclear Power Programme Planning: An Integrated Approach, IAEA-TECDOC-1259 (2001).

Staffing Requirements for Future Small And Medium Reactors (SMRs) Based on Operating Experience and Projections, IAEA-TECDOC-1193 (2001).

Recruitment, Qualification and Training of Personnel for Nuclear Power Plants Safety Guide, Safety Standards Series No. NS-G-2.8 (2002).

Maintaining Knowledge, Training and Infrastructure for Research and Development in Nuclear Safety, INSAG Series No. 16 (2003).

Guidance for the Evaluation of Innovative Nuclear Reactors and Fuel Cycles, Report of Phase 1A of the International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO), IAEA-TECDOC-1362 (2003).

Managing Human Resources in the Nuclear Power Industry: Lessons Learned, IAEA-TECDOC-1364 (2003).

Nuclear Power Industry's Ageing Workforce: Transfer of Knowledge to the Next Generation, IAEA-TECDOC-1399 (2004).

CONTRIBUTORS TO DRAFTING AND REVIEW

Agrawal, V. C.	Nuclear Power Corporation of India Limited
Chwaszczewski, S.	Institute of Atomic Energy, Poland
Diaz, E.	Consultant, Argentina
Goodnight, C.	Goodnight Consulting, Inc., United States of America
Hwang, S-C.	KHNPC, Republic of Korea
Karr, K. R.	Fleet Integration, Dominion Services, Inc., United Sates of America.
Rastas, A.	Consultant, Finland
Sambo, A. S.	Energy Commission of Nigeria
Tiron, C.	Nuclearelectrica – S.A., Cernavoda, Romania
Tshelane, P.	PBMR, South Africa
Vassileva, E.	Kozloduy NPP, Bulgaria

Consultants Meeting
Vienna, Austria: 1–4 March 2005

Technical Meeting
Vienna, Austria: 5–9 December 2005

No. 20, August 2005

IAEA
International Atomic Energy Agency

Where to order IAEA publications

In the following countries IAEA publications may be purchased from the sources listed below, or from major local booksellers. Payment may be made in local currency or with UNESCO coupons.

Australia
DA Information Services, 648 Whitehorse Road, MITCHAM 3132
Telephone: +61 3 9210 7777 • Fax: +61 3 9210 7788
Email: service@dadirect.com.au • Web site: http://www.dadirect.com.au

Belgium
Jean de Lannoy, avenue du Roi 202, B-1190 Brussels
Telephone: +32 2 538 43 08 • Fax: +32 2 538 08 41
Email: jean.de.lannoy@infoboard.be • Web site: http://www.jean-de-lannoy.be

Canada
Bernan Associates, 4611-F Assembly Drive, Lanham, MD 20706-4391, USA
Telephone: 1-800-865-3457 • Fax: 1-800-865-3450
Email: order@bernan.com • Web site: http://www.bernan.com

Renouf Publishing Company Ltd., 1-5369 Canotek Rd., Ottawa, Ontario, K1J 9J3
Telephone: +613 745 2665 • Fax: +613 745 7660
Email: order.dept@renoufbooks.com • Web site: http://www.renoufbooks.com

China
IAEA Publications in Chinese: China Nuclear Energy Industry Corporation, Translation Section, P.O. Box 2103, Beijing

Czech Republic
Suweco CZ, S.R.O. Klecakova 347, 180 21 Praha 9
Telephone: +420 26603 5364 • Fax: +420 28482 1646
Email: nakup@suweco.cz • Web site: http://www.suweco.cz

Finland
Akateeminen Kirjakauppa, PL 128 (Keskuskatu 1), FIN-00101 Helsinki
Telephone: +358 9 121 41 • Fax: +358 9 121 4450
Email: akatilaus@akateeminen.com • Web site: http://www.akateeminen.com

France
Form-Edit, 5, rue Janssen, P.O. Box 25, F-75921 Paris Cedex 19
Telephone: +33 1 42 01 49 49 • Fax: +33 1 42 01 90 90 • Email: formedit@formedit.fr

Lavoisier SAS, 145 rue de Provigny, 94236 Cachan Cedex
Telephone: + 33 1 47 40 67 02 • Fax +33 1 47 40 67 02
Email: romuald.verrier@lavoisier.fr • Web site: http://www.lavoisier.fr

Germany
UNO-Verlag, Vertriebs- und Verlags GmbH, Am Hofgarten 10, D-53113 Bonn
Telephone: + 49 228 94 90 20 • Fax: +49 228 94 90 20 or +49 228 94 90 222
Email: bestellung@uno-verlag.de • Web site: http://www.uno-verlag.de

Hungary
Librotrade Ltd., Book Import, P.O. Box 126, H-1656 Budapest
Telephone: +36 1 257 7777 • Fax: +36 1 257 7472 • Email: books@librotrade.hu

India
Allied Publishers Group, 1st Floor, Dubash House, 15, J. N. Heredia Marg, Ballard Estate, Mumbai 400 001,
Telephone: +91 22 22617926/27 • Fax: +91 22 22617928
Email: alliedpl@vsnl.com • Web site: http://www.alliedpublishers.com

Bookwell, 2/72, Nirankari Colony, Delhi 110009
Telephone: +91 11 23268786, +91 11 23257264 • Fax: +91 11 23281315
Email: bookwell@vsnl.net

Italy
Libreria Scientifica Dott. Lucio di Biasio “AEIOU”, Via Coronelli 6, I-20146 Milan
Telephone: +39 02 48 95 45 52 or 48 95 45 62 • Fax: +39 02 48 95 45 48

Japan
Maruzen Company, Ltd., 13-6 Nihonbashi, 3 chome, Chuo-ku, Tokyo 103-0027
Telephone: +81 3 3275 8582 • Fax: +81 3 3275 9072
Email: journal@maruzen.co.jp • Web site: http://www.maruzen.co.jp

06-17561