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Evaluating and improving nuclear power plant operating performance

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FOREWORD

During the last decade, there have been significant improvements in the worldwide operating performance of nuclear power plants. The world energy availability factor grew from about 72% in 1989 to about 78% in 1997. Although some plants have consistently high energy availability, others have remained below the international averages. There are a number of countries, utilities and plants that have shown consistently high availability practically since the start of operation, while others have remained consistently below average and some utilities have improved their operation management and thereby increased the energy availability factor.

This report aims to provide the basis for improvements in the understanding of nuclear power plant operations and ideas for improving future productivity. The purpose of the project was to identify good practices of operating performance at a few of the world's most productive plants. This report was prepared through a series of consultants meetings, a specialists meeting and an Advisory Group meeting with participation of experts from 23 Member States. The report is based on self-assessment of half a dozen plants that have been chosen as representatives of different reactor types in as many different countries, and the views and assessment of the participants on good practices influencing plant performance.

Three main areas that influence nuclear power plant availability and reliability were identified in the discussions: (1) management practices, (2) personnel characteristics, and (3) working practices. These areas cover causes influencing plant performance under plant management control. In each area the report describes factors or good practices that positively influence plant availability.

The case studies, presented in annexes, contain the plant self-assessment of areas that influence their availability and reliability. Six plants are represented in the case studies: (1) Dukovany (WWER, 1760 MW) in the Czech Republic; (2) Blayais (PWR, 3640 MW) in France; (3) Paks (WWER, 1840 MW) in Hungary; (4) Wolsong 1 (PHWR, 600 MW) in the Republic of Korea; (5) Trillo 1 (PWR, 1066 MW) in Spain; and (6) Limerick (BWR, 2220 MW) in the United States of America.

The preparation of the present report was initiated within the framework of the IAEA's programme for nuclear power plant performance assessment and feedback.

The IAEA wishes to thank all participants and Member States for their valuable contribution. The IAEA is also grateful to M. Ibañez for the preparation of this report and to G. Rothwell for chairing the meetings. The IAEA officer responsible for overall co-ordination and preparation was R. Spiegelberg-Planer of the Division of Nuclear Power.

EDITORIAL NOTE

CONTENTS

1. INTRODUCTION

Currently, about 17% of the world's electricity generation is produced by nuclear power plants. Nuclear power plants which exhibit good operational performance provide a reliable and economic supply of electrical energy consistent with high standards of public and employee safety and protection of the environment. The achievement of longer term good operational performance requires reliable equipment, good management and proficient staff supported by effective procedures and necessary services.

The purpose of this report is to summarize operational principles, practices and improvements which have contributed to good operating performance at a few of the world's most productive plants. Six plants have been chosen as representatives of different reactor types in as many different countries. The plant's self-assessment were complemented by the views of participants of a series of consultants, specialists and Advisory Group meetings held at the IAEA aiming to provide the basis for improvements in the understanding of nuclear power plant operations and ideas for improving future productivity.

Evaluating technical performance is broad in scope. Apart from the technical productivity, i.e. the ability of the plant to produce energy, as measured by the energy availability factor (EAF) and unit capability factor (UCF), other areas must be considered to give a clear picture of the technical behaviour of a plant. Such areas are, for example, environment impacts, industrial safety, radiological protection, safety indicators, scram rate, thermal efficiency, and fuel reliability. Most of these domains are covered by the World Association of Nuclear Operators (WANO) performance indicators. The availability and unavailability indicators are covered by WANO (UCF, UCLF) and more in depth by the International Atomic Energy Agency (IAEA) with the Power Reactor Information System (PRIS).

It is generally considered that good technically-performing plants have consistently good results in all areas. Even if the correlation between all these factors, as ingredients for good performance, is not obvious, there seems to be a link between them, if an overall trend is detected. The diffusion effect for actions or good practices from one area to another depends on numerous factors and is of course difficult to quantify.

Good practices can be often described through qualitative information. It is seldom possible to describe them through quantitative parameters or to identify correlations between trends. In addition, the cumulative effects of various actions cannot allow identification of a clear productivity efficiency ratio to each of these actions or good practices. The inertia of these actions is another difficulty. Identifying quantitatively the contribution of one good practice to the improvement of plant energy availability factor is extremely difficult, because all else must be held constant, which is not possible. The performance indicators for this study are the energy availability factor (EAF) and the planned (PUF) and unplanned energy unavailability factors (UUF). The cumulative EAF (or the unit capability factor, UCF) is a good indicator of the "success" of a plant. A few years (at least three or four) are necessary to be able to build a clear picture of the productivity at each plant.

The publication focuses on short- and medium-term actions and results, and the best practices that can be considered to participate and contribute to them.

This report contains five sections. This introduction contains preliminary remarks. Section 2 presents a review of worldwide performance indicators. Section 3 is a presentation of the case studies. The overview of the nuclear power plants management practices, personnel characteristics and working practices implementation covered by the case studies can be found in Section 4 of this report. Specific conclusions are presented in Section 5. The bases for both Sections 4 and 5 were written collectively by the authors of the case studies and the participants of the Advisory Group Meeting on Evaluation of Plant Technical Performance held in June 1997 in Vienna. These sections present the consensus of these experts *regarding best common or individual good practices* that can be used at nuclear power plants with the aim to improve their performance in relation with operational safety and availability.

2. WORLDWIDE PERFORMANCE BASED ON AVAILABILITY AND UNAVAILABILITY RESULTS

The basic performance indicators for this study are the energy availability factor (EAF) and the planned (PUF) and unplanned energy unavailability factors (UUF). The energy availability factor is the ratio of the actual energy generation (net) in a given period, expressed as a percentage of the maximum energy that could have been produced during that period by continuous operation at the reference capacity. Energy losses are considered to be planned if they are scheduled at least four weeks in advance. Planned energy losses are considered to be under plant management control and include losses due to planned outages for refuelling, maintenance, testing, etc. Unplanned energy losses include losses due to unplanned outages for maintenance, testing, repair, etc., and also include energy losses through causes beyond the control of management.

An analysis of the data available in the IAEA Power Reactor Information System (PRIS) indicates that there has been a steady improvement in the world average energy availability factor since 1980 as shown in Figure 1. The EAF grew from about 72% in 1989 to about 78% in 1996.

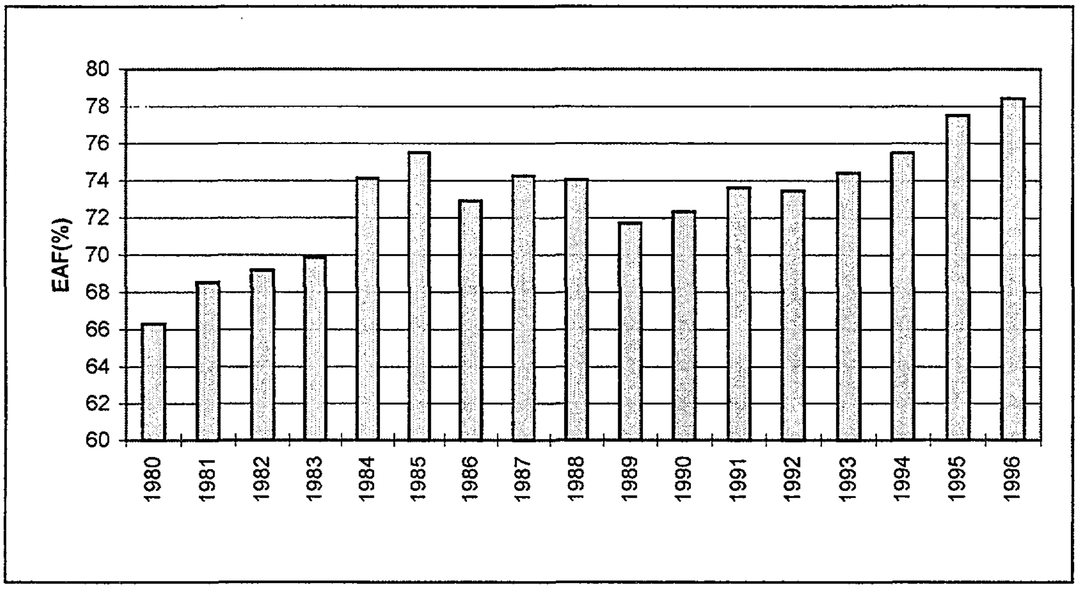

FIG. 1. World Average Energy availability factors.

The number of plants presenting high energy availability factors (greater than 75%) also has increased as shown in Figure 2.

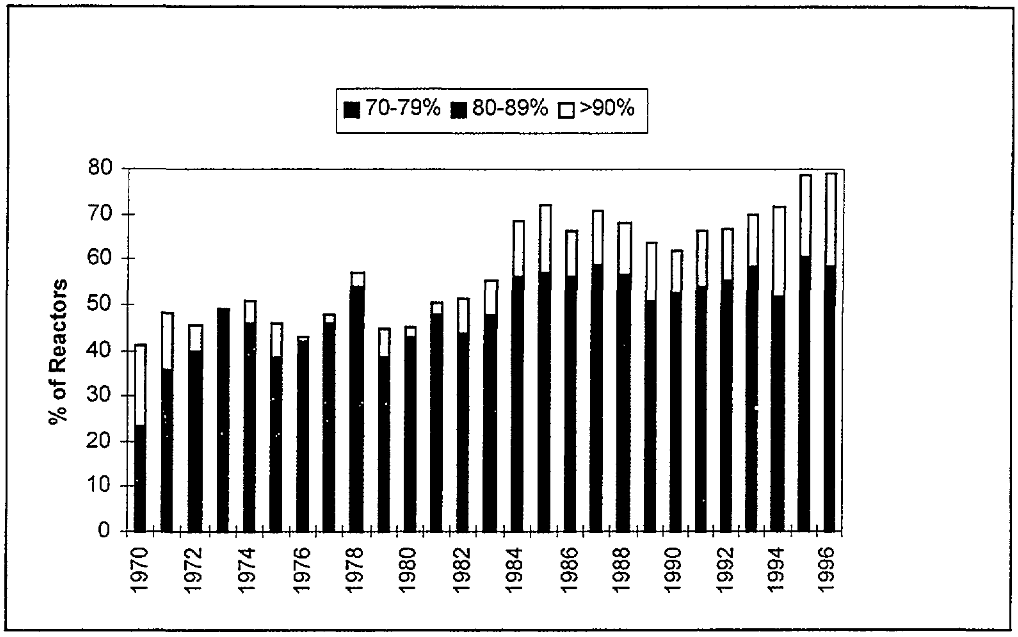

FIG. 2. Distribution of reactors with high availability factor.

The cumulative world energy availability factor up to 1996, since beginning of commercial operation and for non-prototype reactors is 73%, while the planned energy unavailability factor (PUF) is 17.4%.

There is a steady decrease in both planned and unplanned energy unavailability factors over the last years indicating a continuing improvement in plant maintenance management (Figure 3). The average planned energy unavailability factor for the period 1988–1990 was about 19%. This value decrease to about 15% in the period 1994–1996. The improvement in the unplanned energy unavailability factor was also significant.

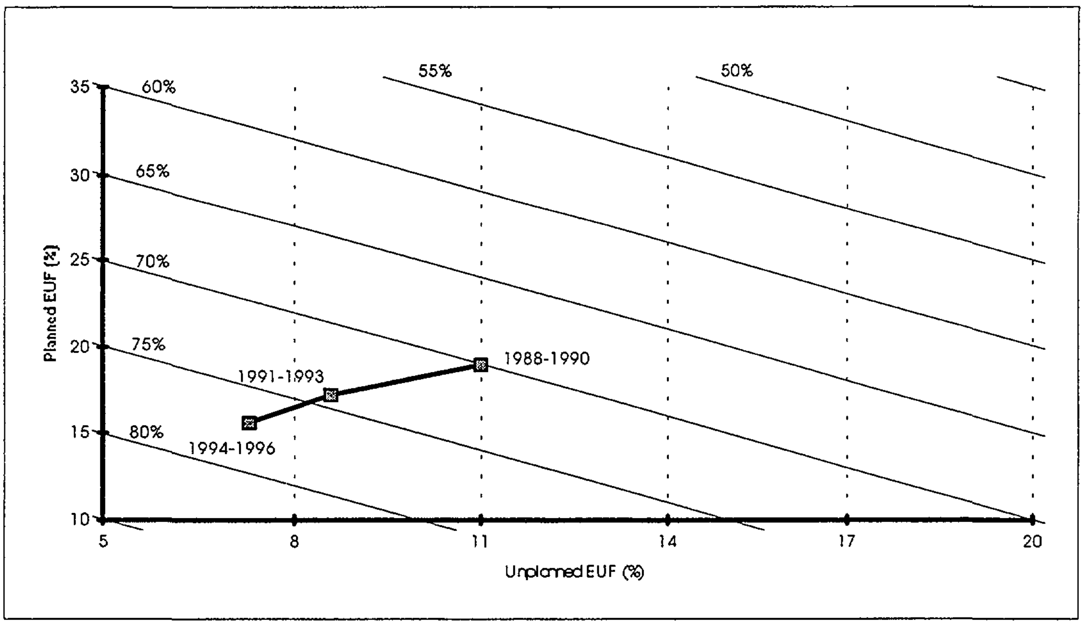

FIG. 3. Average availability and unavailability factors (1988–1990, 1991–1993, 1994–1996).

These improvements can be attributed to a process of learning from experience. However, a number of initiatives taken by the Member States and the IAEA have a significant role in the achievement of sustained improvement in the overall performance of the plants.

Survey by reactor type

A survey by reactor type shows that there is a considerable increase in the availability of BWR, PWR and AGR units. The PWR units improved the energy availability factor from 72% (average between 1988–1990) to 80% (average between 1994–1996). The BWR units increased the energy availability factor from 68% (average between 1988–1990) to about 77% (average between 1994–1996). The PHWR units kept the level of performance, achieving 74.5% in the period 1994–1996. The WWER and LWGR units presented a decrease in the availability, showing a trend to recover in the last years. The availability of WWER units, as well as the LWGR (or RBMK) type reactors shows the impact of the backfittings and other maintenance programmes since 1990.

Figure 4 presents the average energy availability and unavailability values in last three years period (1994–1996) by reactor type.

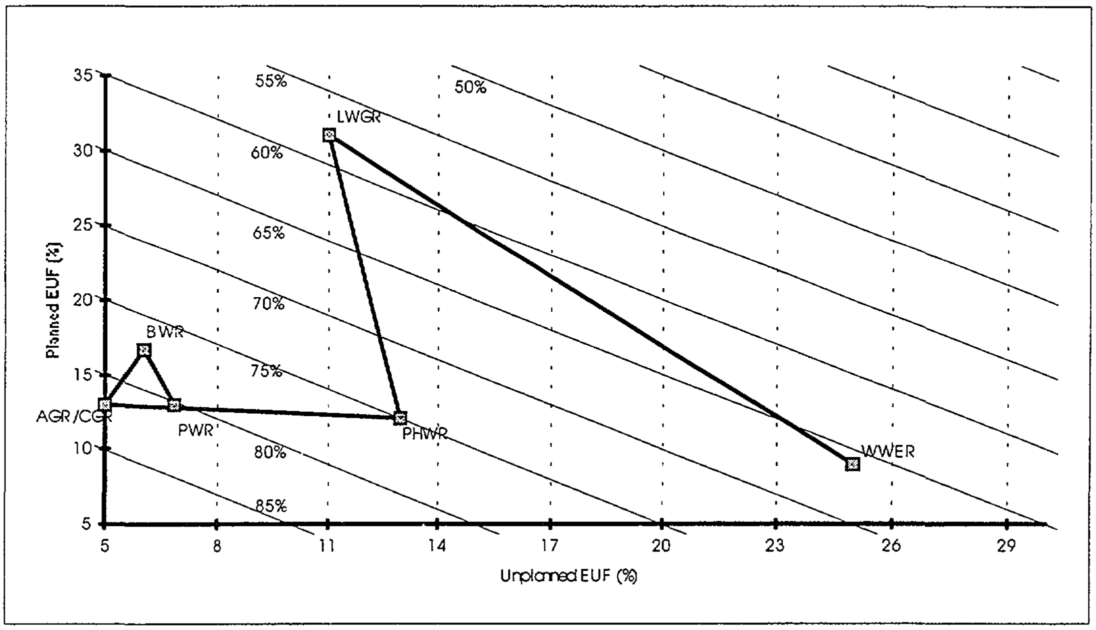

FIG. 4. Availability and unavailability factors by reactor type (1994–1996).

3. PRESENTATION OF THE CASE STUDIES

3.1. OVERVIEW OF THE CASE STUDIES

The case studies of the plants covered by this report follow the contents of Annex A, Case study guidelines.

Some of the good performing plants of different reactor type were invited to participate in the creation of a case study survey and in preparing a case study of their plants.

The individual case studies discuss the activities and plans carried on by each plant to be operated with a high standard of safety, availability and reliability. A correlation could be made between the activities that could be considered as good practices or guidelines for other plants to reach similar levels of performance.

Each of the case studies has four sections:

(1) **Plant description**, where the plant's operator, location, size, technology, etc., are identified.

(2) **Historical performance**, where performance indicators for the 1990s and events related are analysed.

(3) **Overview of the Case Study**, where the main findings are presented.

(4) **Managing and working at the NPP**, where management practices, personnel characteristics and training, and working practices are discussed.

The case studies followed the guidelines presented in Annex A, nevertheless some subsections were omitted and others were added to individual case studies where appropriate. Each of the case studies was written independently and can be read as a stand alone document. A summary of the plants' description is contained in Section 3.2.

The historical performance of the plants are fully described in the case studies. The main issues underlined emphasised the following:

– Solving first the problems associated with initial design and deficiencies observed during start-up and first phases of the commercial operation, or improvements of the original design;
– Close following of the performance indicators trends. The studies contain several tables with historical trends using IAEA and WANO performance indicators, INES events, personnel qualifications, staff numbers, etc. for the period 1990–1995;
– Creation of a pleasant working environment;
– Maintenance of a good availability as a result of the following major elements:
  - controlling the outage activities;
  - maintaining very low unplanned unavailability factor;
  - reducing plant transients caused by human errors or component failure;
  - improving thermal efficiency;
  - housekeeping of the facilities;
  - minimizing plant ageing;
  - staffing optimization.

3.2. PLANTS CHARACTERISTICS

Each case study contains a section presenting the plant description with main characteristics of the plants: number of units, type of reactor, dates of first criticality, connection to grid, commercial operation and other technical matters (Annex B, C, D, E, F, G).

The main characteristics of the plants analysed are:

- *Dukovany* is a 4-unit WWER-440/213 with a total capacity of 1760 MW, operating in the Czech Republic by the Czech Power Company. Dukovany's Unit 1 began commercial operation in November 1985 and Unit 4 began commercial operation in January 1988. Because every fourth year an extended maintenance outage occurs at each unit, four-year averages of performance indicators are calculated. The EAF at Dukovany averaged 82% between 1992 and 1995.
- *Blayais* is a 4-unit PWR with a total capacity of 3640 MW, operating in France by Electricite de France. Blayais Unit 1 began commercial operation in December 1981 and Unit 4 began commercial operation in October 1983. The EAF increased from 78% in 1990 to 84% in 1995 despite a ten-year special maintenance outage in 1995 at Unit 4.
- *Paks* is a 4-unit WWER-440/213 with a total capacity of 1840 MW, operating in Hungary by the Hungarian Electric Energy Board. Paks Unit 1 began commercial operation in August 1983 and Unit 4 began commercial operation in November 1987. The EAF increased slightly during the 1990s to 85% in 1995.
- *Wolsong* Unit 1 is the first unit of a 4-unit CANDU-PHWR with a capacity of 600 MW, operating in the Republic of Korea by the Korean Electric Power Corporation. Wolsong Unit 1 began commercial operation in April 1983. Wolsong 2, 3 and 4 are 700 MW PHWRs. Worlsong 2 started operation in 1997, units 3 and 4 are planned to begin commercial operation in 1998, and 1999. The average EAF from 1990 to 1995 was 87%.
- *Trillo* is a single-unit (Siemens-KWU) PWR with a capacity of 1066 MW, operating in Spain by a Business Group for four electric utility owners. Trillo 1 began commercial operation in June 1988. From 1990 to 1995, the EAF at Trillo averaged 85%, increasing from 75% in 1990 to 86% in 1995.
- *Limerick* is a two-unit BWR with a total capacity of 2220 MW, operating in the USA by PECO Nuclear, a unit of PECO Energy (formerly known as Philadelphia Electric Company). Limerick Unit 1 began commercial operation in February 1986 and Unit 2 began commercial operation in January 1990. The average EAF between 1990 and 1995 for Unit 1 was 84% and was 90% for Unit 2 from 1991 to 1995.

4. IMPROVING NUCLEAR POWER PLANT PERFORMANCE

This chapter presents best common or individual good practices identified in each of the six nuclear power plants case studies included in Annexes B to G, and on discussion with other utilities or operators through a series of meetings held at the IAEA. The structure of this chapter follows the case study guidelines as described in the Annex A.

The two common aspects of all plants included in the report are: (1) the high EAF and, (2) a positive evolution in the last years in relation to safety, availability and reliability. The fact that these plants are from different technologies, different suppliers, several vintages, different number of units at site (from 1 to 4 units), sites with units under construction and operation simultaneously, several economics/properties configuration, etc. makes more interesting the results presented here.

4.1. MANAGEMENT PRACTICES

The purpose of this section is to describe facts of plant management responsibility that are directly linked with good plant performance. These facts have been classified in the following areas:

- Organizational structure
- Strategy and goals
- Management involvement and communication
- Managing quality
- Relationship with contractors
- Budget resources and allocation.

In general, developments in these areas are originated in the plant operating company philosophy, which is propagated to all employees and contractors through the contents of the "mission", "vision" and "values of the plant". The plants analysed adopted management goals through the following self-explanatory plant statements:

- To be the best in the nuclear business;
- To provide service to the public by supplying electricity with safety and quality at competitive prices, increasing the quality of life and customer well-being;
- To be a technical and economic leader;
- To be one of the best operated plants in the world.

All of the above statements are ideas to develop: essential values (company roots), cultural principles, policies, strategies/plans and assessment of the results at the end of year or fuel cycle.

The core values of the plant included in the management philosophy for all the employees to achieve are:

- Safety respect for the environment
- Economical competitivity
- Team spirit employees/contractors
- Participation and communication
- Accountability, trust and respect
- Ethics and integrity
- Continuous learning
- ALARA principles
- Openness and exchange of experience with other operators, benchmarking analysis
- Individual professionalism
- Ageing management.

4.1.1. Organizational structure

Although there are differences between the organizational structures of the plants and the utility or utilities owning them, the plant's organizational chart reflects the management's philosophy.

The following common factors were identified in the organizational structure as having positively influenced plant performance:

- In all stations, the different managerial levels are clearly identified and the numbers of levels have been reduced (flatter organizations).
- The plant documentation clearly identifies the responsibilities and relationships between the individuals of the staff at the corporate level (headquarters) and at the site. The organizational structure should be clear and well understood by everyone.
- Clear assignments and delegations have been formalized. For example: financial and technical authority delegated to department managers or to first line managers/supervisors. This enhances responsibility and commitment. All aspects of decision making authority (technical and financial issues) should be located as close to the first line supervisor as possible.
- The different organizational charts experienced several changes and staff reduction to improve performance. It is clearly understood that, without previous analysis and appropriate actions, staff reduction can not be solely related with an improved organizational structure. Some of the actions taken to optimize plant organizational structure are to:

  - Perform re-engineering and design review studies
  - Use off-site support organizations
  - Concentrate plant employees at the site
  - Enhance work management process and management practices
  - Focus plant personnel on plant safety and operation
  - Modify fuel cycle length strategy
  - Transform maintenance department into private companies
  - Create working committees across departments
  - Use maintenance personnel between outages.

Other changes in the organizations, as for example cross training of managers and employees has enabled reduction in the numbers of both permanent plant employees and contractors. Table II compares **permanent plant employees per MW** across plants showing the general trend to decrease this number.

TABLE I. PERMANENT PLANT EMPLOYEES PER INSTALLED MW

	1990	1991	1992	1993	1994	1995
Dukovany	1.56	1.47	1.41	1.12	1.03	1.00
Blayais	0.29	0.29	0.29	0.30	0.30	0.30
Paks	(-)	(-)	(-)	1.90	1.84	1.77
Wolsong	0.43	0.42	0.41	0.43	0.41	0.40
Trillo	0.39	0.39	0.39	0.38	0.37	0.37
Limerick	(-)	(-)	0.65	0.59	0.57	0.47

Note: (-) not provided

4.1.2. Strategy and goals

The most important factor is to enhance the common understanding of clear goals and expectations contained in the corporate project and the plant strategy plan, which are considered reference documents to direct the efforts of the plant's staff.

Although strategy plans can present different duration in each plant — three, five or ten years, they are based on similar ideas:

- The main reference is the vision, mission and core values of the company. Strategic and specific action plans are periodically reviewed, but the specific action plans are reviewed more frequently than the strategy plan.
- Wide involvement of the personnel in the development of the plan gives consistency to the planned actions;
- Establishment of numerical achievable goals for a set of performance indicators and periodic controls to alert when performance declines. A benchmarking program could help to identify the goals required. (The evolution of some performance indicators during the period 1990–1995 are presented in the case studies.);
- Establishment of business plans for all cost centers (operations, maintenance, technical support, administration, etc.);
- Creation of personnel incentive programmes.

- Some issues and actions for better implementation of strategic plans are:

- A big effort in informing and communicating to employees and contractors past results and objectives, and future actions.
- Management is responsible for ensuring that their employees have the resources required to achieve the organizations goals.
- Monthly and daily plans could be created for each employee and team. Personal goals could be established at the start of each year, monitored during the year and evaluated at the end of the year.
- Accomplishing goals provides basis for managers and employees appraisal, career planning and self improvement programmes.

Other initiatives or strategies are:
- Development of risk analysis culture and reinforcement of preventive maintenance activities based on reliability centred maintenance;
- Maintain the option for life extension open;
- Positive reinforcement of strategies and goals;
- Appointment of a strategy manager to sponsor each goal;
- Anticipation of major generic problems;
- Provision of relevant information to all users;
- Maintain good relationship with the public.

4.1.3. Management involvement and communication

It is recognized a good practice when the management take a personal and active role in the daily conduct of operation at the plant. Some methods to implement this were outlined in the case studies and summarized below:

- Involve appropriate manager in daily meetings;
- Invite different personnel of the staff to attend "management meetings";
- Participate on self-assessments;
- Establish a plant touring by line manager in each shift, with the objective to assess the plant condition together with plant operators, monitor systems performance, obtain data or plant process parameters and observe the compliance with industrial, safety and radiological protection policies.

Management involvement creates an atmosphere of openness, in which mistakes are brought to management attention, not to put the blame on the individual, but to be used as opportunities for learning.

All case studies mention the importance of communications at different levels:

- With external organizations (IAEA, WANO) and with other power plants (benchmarking) to share technical data and operating experiences;
- With the surrounding communities, local governments, media, etc. to maintain the transparency and good image of the plant. Some examples used are the information centers and magazine, brochure or other publications used for public information;
- Other principles were also identified as important to improve internal communications:
    - Establishment of a system of regular meetings and communications to disseminate information, management decisions, goals and results reaching every level of the organization. The infrastructure could include in house bulletins, notice board at the entrance hall, computer network (LAN), etc.
    - Existance of management information system (computerized) to help monitor, analyse and evaluate performance.
    - Communication process which provides timely information and encourages employee feedback.

4.1.4. Managing quality

The case study plants have a quality assurance (QA) programme that has been periodically reviewed to use new techniques and programmes (total quality management — TQM, ISO-9000, quality to line[1], etc.). The management should be committed to quality and must involve all employees in quality assurance.

The total quality management using self evaluation techniques is widely implemented, the ISO-9000 is required by some plants, in others the plant's requirements are stronger.

The goal of quality management is to reach and sustain high performance by identifying weak points in the quality of plant operators, finding their causes and taking corrective measures. Management should develop quality oriented policies covering all immediate operational tasks and strategy goals. This has been done by creating several layers of personnel to insure quality in task and goal performance.

High levels of quality have been reached and sustained at the plants covered by this report through the following activities:

- developing training and qualifying programmes to assist in implementing new techniques (TQM, ISO-9000, etc.);
- internal audits to check the accomplishment of the programmes;
- external audits to qualify the contractors and to verify that their QA procedures comply with plant requirements. Alternatives are the use of nuclear utility organizations or independent consultant to evaluate vendors and contractors;
- performing in depth surveillance of recurring quality problems;
- preventing violations of the quality assurance programme;

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[1] Quality to line is when line management takes responsibility for quality.

- transferring quality inspection activities to operations, maintenance and support crews that have been trained and qualified as authorized inspectors according to QA procedures (moving quality to line);
- developing programmes (periodic revisions) that incorporate quality control into every plant procedure;
- performing root cause analysis of deficiencies in safety or productivity;
- performing risk analysis of the safety implications of each task;
- visiting other plants at national and international level to learn good practices;
- participating in cross disciplinary training to reduce the number of specific crafts;
- developing programs for performance upgrading;
- creating a system of self-assessment at each management level and for each work team.

4.1.5. Relationship with contractors

The use of contractors depends on the role of the off-site support groups, the work to be performed and the expectation of plant management. The highest need for an external contractor is obviously during the outages. In most of the cases, personnel from the same enterprises are used for all plant outages. Many plants have a "permanent contractor".

Contractors are mostly used in: security forces, health physics and radwaste technicians, housekeeping, clerks and mechanical maintenance. In all cases, plant employees maintain responsibility for safety.

Nevertheless, there are differences between plants with respect to how they use contractual support, some common facts can be highlighted:

- mid or long term contracts improve company visibility and job stability;
- contractors are held to the same standard as the plant employees — providing them the specific goals and objectives to:
  - perform all work safely
  - perform all work efficiently (with extended use of mock-ups)
  - perform all work within station procedures, practices, and guidelines
  - provide a quality product
  - minimize radiation exposure (ALARA principle)
  - maintain good housekeeping
  - communicate needs, expectations, problems, and progress
  - self check all work.
- training programmes required for all contractors;
- contractors are required to adhere to plant procedures and QA programme;
- participation of the contractors management teams in the station meetings and with the outage management before the outage.

Beyond these general guidelines, the use of contractors varies across the plants in the case studies. At one end of the range of the use of contractors, Dukovany has privatized its maintenance departments to the extent that all operational maintenance is supplied by contractors. For example, in 1996 there were 1719 permanent plant employees and 2656 contract employees. Similarly, most of the maintenance has been contracted out at Wolsong (utility employees maintain safety and major process systems). In 1996 there were 239 permanent employees and 236 contractor employees. Some of the departments have been privatised at Paks to decrease the number of permanent employees (about 3000) and full time contractors (800). At the other end of the range are Trillo and Limerick where there has been an active effort to reduce the number of contractor personnel, assigning as many non outage tasks as possible to employees. During normal operation in 1997, there were 84 contractors personnel at Trillo. During normal operation in 1995, there were 105 contractor personnel at Limerick, primarily working in security and as radioactive waste technicians. Between these two approaches, Blayais works actively to develop the capabilities of its contractors (about 1000, mainly during the refuelling outages), Electricité de France formalized a "Progress Charter" with the representative organizations of subcontract companies to: (a) improve communications, (b) reduce exposure, (c) establish identical medical follow up for the employees and (d) improve working and living conditions.

4.1.6. Budget and resource allocation

Management is responsible for ensuring that funding is available to support the activities required to achieve the business plan. Although managers are challenged to reduce their expenses, senior management should ensure that budget cuts will not jeopardize plant safety or performance. Only two case studies discuss their budget: Wolsong and Limerick NPPs. Both of them discuss the budget allocation process and provide data on the allocation of resources among plant divisions for five years (Annex E and G). Although this report does not assess budget and resource allocations, there are other IAEA activities dealing with this subject. (reference)

4.2. PERSONNEL

The case studies reflect a common understanding that the people are the key factor for good operating performance.

The work force is a combination of utility employees, permanent and temporary contractors (mainly and in an extend number during the outages). The contractual philosophy is described in Section 4.1.

The purpose of this section is to describe the usual practices, related to: (1) personnel characteristics, (2) personnel development and training and (3) personnel behaviour and attitudes, that have direct influence in the plant performance.

4.2.1. Personnel characteristics

The analysis of plants requirements for personnel shows the importance of the three following phases:

- Selection process taking into account educational level, physical and mental conditions;
- Initial training and retraining;
- Professional development.

The aspects identified in contributing to improvements in work force characteristics are:

- Positive trend in the indicator of the educational level with an increase in the proportion of the personnel with high level of education. This allows the reduction of the workcraft numbers and the increase in engineering, planning, preparing and checking activities to reinforce preparation of the work.
- Need of sub contracted personnel with extremely specific technical skills for temporary activities.
- Establishment of long term plans to cover ageing of staff.

- Positive evolution of productivity (kW h/employee) in the last years.
- Experienced staff in plant construction, erection, testing and operation.
- High stability of workforce and trend to move headquarters personnel to site.
- Reduction of a workforce as result of improved organization, cross training activities, job rotations, simplified processes, retention of the best qualified personnel, introduction of radiation protection practices in the mechanical and electrical craft team, very detailed outage and non outage schedules, pooling clerks and providing administrative controls, moving activities into the line organizations, etc.

4.2.2. Personnel development and training

Management is responsible for ensuring that all employees have the skills to perform their jobs. Priority should be given for development of management and leadership skills. To comply with this objective, tools should be provided to individuals for the preparation of future assignments or for future leadership positions. Opportunities for individuals to develop themselves for job changes should be created. Job rotation of personnel should be encouraged. Employees should be able to express their wishes at periodic career evaluations with their supervisors. This enables staff to become more involved in planning their professional careers.

Some good plant practices identified in this study are:

- Training programmes divided into basic and refresher training with the idea of *"continuous training"* philosophy, learning from others and sharing individual knowledge.
- In some plants, staff training is completed by a final exam. Initial training is completed with on-the-job training.
- Specific training programmes prepared for operations personnel. Beside the use of simulators, it is very important to discuss: plant modifications, procedures changes, operational experience, events analysis.
- Improve the quality of training with different tools and programs contents, such as:
  - Quality of instructors and training packages;
  - Knowledge on physical processes;
  - Development of analytic capabilities in normal and accident operation conditions;
  - Full screen simulators, functions and engineering simulators;
  - Static and dynamics mock-ups;
  - Course effectiveness measurement;
  - Trainee feedback and management involvement.

The main aspects to improve human factors training are:

- Training materials for plant personnel working in more than one building or areas including: (1) Elaboration of individual professional plans (co-ordinating individuals wishes and company needs), specific knowledge and skills, (2) learning objectives, (3) job task description, (4) equipment layout drawings, and (5) important procedural steps for performing various system operational evaluations.
- Expansion of basic radiation worker training to include more in depth coverage of contamination control practices to reduce contamination events.
- Individual training notebooks kept by every reactor operator to take note of personal views during training concerning operation, procedure, etc. The opjective is to improve the training performance and to provide feedback for subsequent training sessions.

- Accountability of line organization for training and development of their staff with guidance and supervision of the training organization.

There are differences between the number of training hours at the different plants or the impact of them in the annual budget. Nevertheless, there is a trend to increase training in areas related to management courses (corporate project, strategic plan), managerial and leadership development, human performance, etc.

4.2.3. Personnel behaviour and attitudes

This sub-section identifies measures and actions that influence personnel behaviour and attitudes leading to a healthy working environment and improved plant performance. Some of these measures and actions are:

- Development of a feeling of responsibility and ownership;
- Implementation of courses to improve behaviour and attitude:
  - IAEA ASSET methodology and safety culture course
  - Human performance enhancement courses
  - Self checking, teamwork, effective communication courses;
- Existence of appraisal system to measure individual identified selected behaviours and ensure that nuclear and personal safety are the first and primary values.
- Emphasis by line management on the importance of safe work practices and reinforcement of safety practices in pre-work activity briefing;
- Implementation of performance enhancement programs on safety related issues, daily operations, operating experiences, human performance issues, and near misses;
- Motivation programs.

4.3. WORKING PRACTICES

This section identifies the working practices, at the plants covered by the case studies that have positive effect on the plant availability These practices are classified in the following five fields: (1) plant status control, (2) operations, (3) maintenance, (4) technical support and (5) interaction between work groups.

4.3.1. Plant status control

Continuous monitoring of the status of the station systems and components is essential to detect equipment deficiencies and abnormal unit conditions.

Plant status control is aided by:

- Continuous plant monitoring at the main control room by the licensed operators and walk-rounds by auxiliary operators (including the emergency control room) to check for any anomalies or deficiencies and write down selected parameters. The shift supervisors check with auxiliary operators the walk-round results either manually or with a computerized data log. If a problem is detected a work request is issued. An upgraded alarm system and plant computer is widely recommended.
- Periodic on-shift emergency operation drill focused to check the applicability of the emergency procedures during the accident scenario selected.
- Detailed turnover of information regarding equipment status, in-process testing, current status of the active clearances and specification limitations.

- On-line (computerized) information system — local area network (LAN) — regarding equipment status linked to task completion and technical specifications.
- A "*fix-it-now*" or "*maintenance by operators*" approach to high priority tasks and safety related equipment.
- Periodic checking of temporary modifications.

4.3.2. Operations

Improving the quality of operating procedures and providing high quality of operating aids minimizes human related errors, maximizes the timely, effective response to abnormal conditions and improves operator productivity. Further, operation quality could be enhanced through:

- Using a clear methodology for developing and revising procedures;
- Preparing procedures with a team of qualified operations and engineering personnel;
- Using operating flow diagrams in a digitised form and processed by computer graphics;
- Establishing specific management system for "*sensitive operations transients*" related to safety through the following steps: (a) identification of "*sensitive transients*", (b) pre-analysis of risk to nuclear safety, (c) identification of preventive measures taken to ensure nuclear safety functions.
- Conducting operation of critical equipment by more than one operator.
- Posting related drawings and procedures in the vicinity of major equipments. Labelling and identifying equipment, for example, with colour-coding (of fluids, systems, etc.) and with directional identification of pipes and valves.
- Using plastic covers on specific control panels to prevent inadvertent actuation and operator error.
- Using temporary or permanent locks on important equipment.
- Installing permanent scaffolding, hoist, drain and venting hoses for safe and quick access to equipment and safety operation.
- Being prepared for seasonal problems.

4.3.3. Maintenance

Although maintenance policy focuses on the allocation of maintenance resources to predictive, preventive, and corrective maintenance; many plants are moving toward reliability centred maintenance (RCM).

High availability depends on success during outages and minimization of unplanned outages. Taking into account that the majority of the work is carried out during outages, success depends on planning and work preparation. All forms of planning are aided by computer systems and advanced co-ordination of the maintenance activities and spares management.

The effectiveness of maintenance activities could be enhanced through:

- Keeping a positive trend in maintenance backlog clearance (this is an important indicator of maintenance management efficiency).
- Using maintenance indicators such as: number of work requests, ratio between preventive and total maintenance, pending preventive activities, number of repetitions of work on the same component or system and others.

- Readyness to eventual unplanned outage by maintaining work list showing jobs in three categories: (a) those that can be accomplished with the plant in hot standby,(b) those that must be done with the plant in cold shutdown and (c) those that require refuelling outage conditions. This information should be maintained on a computerized program that includes parts inventories, labour force scheduling, etc.
- Reliability and condition based decision analysis using detailed databases and on-line monitoring of plant equipment to reduce preventive maintenance.
- Advanced planning of routine maintenance and outages using mock-ups, areas surrogate, tour on video laser disc, etc.
- Conduct maintenance with plant approved procedures.
- Strict adherence to foreign material exclusion programme to protect plant equipment, including documentation for materials used with open systems.
- Work briefings and post maintenance testing to verify completion of work and readiness for operation including analysis of the work done.
- Performing on-line maintenance based on PSA studies.

4.3.4. Technical support and other activities

Technical support teams test, analyse, and propose appropriate corrective actions. The description of the role of the technical support varies across the plants, but some ideas about how technical support could be improved are:

- Use of system manager (responsible for all aspects related to system, including work management, troubleshooting and assessment of system condition);
- Use of benchmarking and evaluation processes (IAEA, OSART and ASSET mission and WANO Peer Reviews);
- Use of operating experience information for plant upgrades, procedures enhancement and process improvements.
- Creation of specific operations group for technical services to support medium and long-term operations and maintenance tasks;
- Use of an engineering organization to plan modernization of equipment and safety upgrade.

4.3.5. Interaction between work groups

Interaction and communication between different work groups could be improved by:

- Using "customer-supplier" relationship between plant and headquarters and among department work teams (example is given in Figure 5);
- Routine meetings with all department managers to discuss problems and adjust work schedules;
- Establishing interdisciplinary teams to address urgent or specific problems;
- Encouraging managers and supervisors to work with department teams.

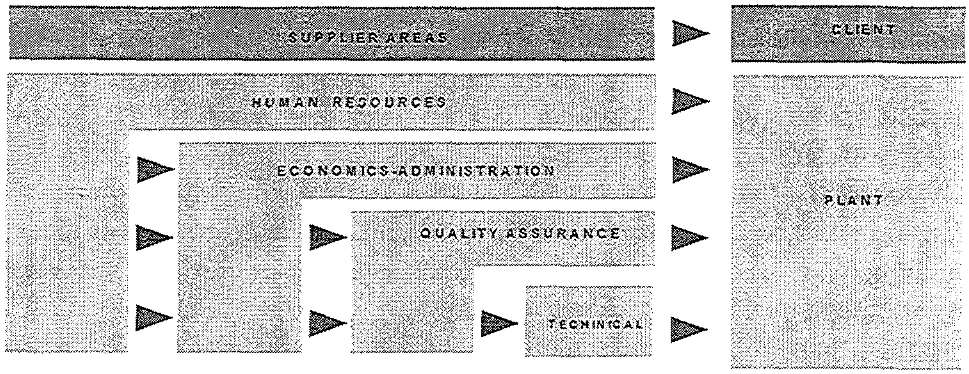


FIG.5. Supplier-client relationship.

5. MAIN FINDINGS AND CONCLUSIONS

There is a wide agreement between countries, utilities, and plants regarding recognised good practices for plant technical performance improvements. Although each one is valuable, their implementation in other plants might differ, due to, for example, costs and benefits that differ from country to country. Improvements come from strategies that could apply to one plant or to all plants operated by the same utility. The most important strategies identified are:

- Establishing an organization based on company philosophy (mission, vision and values of the plant) principles where the different managerial levels are clearly identified and limited (flatter organization).
- Establishing clear goals and objectives for corporate project and strategy plan to be acknowledged by plant staff.
- Promoting performance improvement as a general and systematic goal of all plant departments, utility and contractors personnel
- Implementation of risk analysis culture and reinforcement of preventive maintenance activities based on reliability centred maintenance to optimize duration and location of maintenance activities during plant outages and minimize unplanned outages.
- Promoting involvement of plant management in daily conduct of plants operations and communications activities.
- Implementing techniques, work management, quality assurance, etc. using appropriate technological and managerial tools.
- Considering longer fuel cycles strategies to increase capacity factor.
- Maintaining high level of safety at the plant, well motivated personnel and excellent equipment conditions.
- Establishing self-assessment programs with external support from other nuclear power plants or organizations (IAEA and WANO).

Some of the most important issues for the implementation of these strategies aiming to improve nuclear power plant performance are:

- Organizational documents clearly reflecting responsibilities and delegation of assignments between headquarters, site management, and department work teams.
- Goals, expectations, and business plan evaluated and updated periodically to provide a systematic approach to performance enhancement.
- Atmosphere of openness, in which mistakes are brought to management's attention to be used as opportunities for learning.
- Management committed to quality;
- Involvement of all employees in quality assurance by identifying weak points in the quality of plant operations, finding their causes, and devising corrective measures.
- Contractors with same responsibility and goals as utility employees, and acknowledging utility and plant goals, expectations, and values.
- Management responsible for developing job skills, managerial and leadership potential through training, emphasizing the pursuit of higher education, and job rotation to increase common knowledge for the entire staff.
- Improving the quality of operating procedures and providing high quality operating aids to minimize human related errors and maximize timely, effective response to abnormal conditions. One important operating aid is a computerized information system to provide real time plant status.
- Improved plant reliability through effective maintenance policies, planning and performance. Use of condition based decision analysis with detailed databases and on-line monitoring of plant equipment could reduce preventive maintenance.
- Use of operating experience information for plant upgrades, procedural enhancements, and process improvements to improve technical support.
- Interaction and communication between and among groups improved by using "customer-supplier" relationship between departments and establishment of interdisciplinary teams to address urgent or specific problems.

Also, the wide use of local, national, and international experience in improving technical performance has been (and is) highly beneficial in developing excellence. It is of the highest interest to continue these international exchanges to develop their richness and diversity for the benefit of worldwide nuclear operators. Associated with these exchanges, internationally recognised performance indicators (monthly, quarterly, annual, and multiyear) as benchmarks are useful to evaluate technical and managerial improvements. Activities to emulate the best plants in the industry to meet the goals of a strategy plan are beneficial to both individual plants and the nuclear power industry.

ANNEXES A–G

Annex A: CASE STUDY GUIDELINES

1. PLANT DESCRIPTION

This section should present an overview of the plant, including its main design features, utility organization and country requirements, and local environmental conditions affecting energy availability.

2. HISTORICAL PERFORMANCE

Chapter 2 presented international availability and productivity indicators. More detailed information is requested here to allow meaningful comparisons among the plants described in the case studies. Other indicators (outside PRIS and WANO scope) could also be presented and discussed, if there is a link between the observed trends and availability results. Some direct and indirect factors (qualitative or quantitative) could be identified to explain changes in trends in improving or decreasing performance (for example, occurrence of extended planned outages, steam generator replacement, regulatory requirements, etc.).

3. OVERVIEW OF THE CASE STUDY

This section should (1) summarize the main aspects of management practices, personnel characteristics and training, and working practices that have contributed to high plant availability, (2) identify unique practices at the plant, and (3) alert readers to specific sections of the case study.

4. MANAGING AND WORKING AT A NUCLEAR POWER PLANT

4.1. Management Practices

This section describes the general philosophy underlying the plant's management. It introduces factors under management control that influence plant performance: (1) organizational structure, (2) strategy and goals, (3) management involvement and communication, (4) managing quality, (5) relationships with contractors, and (6) budget and resource allocation.

4.1.1. Organizational structure

This section should identify and illustrate the conceptual framework of the NPP organization and how it has influenced plant availability. Responsibilities of plant director (manager) and responsibilities of utility (owner) should be clearly identified. Organizational structure including a description of levels of management hierarchy should be illustrated. Organizational changes during the 1990s, the reasons for these changes, and their effectiveness could be discussed to illustrate how they affected plant availability or helped to keep standards high. A system of delegation of responsibilities at each management level (headquarters, divisions, sections, and departments) should be described. The number of permanent employees, the number of contractor's employees, and the power productivity (MW h) per employee (permanent or total) could be compared across years here or in Section 4.2.1. The management's organizational tools could be described, for example, director's orders, management standards, and effectiveness of their use.

4.1.2. Strategy and goals

The existence of a strategic plan (annual or long term) is often considered a reference document for directing the efforts of the people involved (directly or indirectly) in the operation of the plant. It expresses the management's point of view and the staff's contribution. It expresses what to do to reach the highest quality of service and safety with a limited budget and constraints. Apart from safety and costs, the strategic plan might include expectations of future levels of service. The discussion should describe how the strategic plan has been communicated to each employee and how it integrates day-to-day planning and the prioritising and co-ordinating of tasks. Further, the discussion should identify the methods for evaluating the effectiveness of implementing the management's goals.

Goals or objectives are part of a strategic plan: numerical values are given as references for measuring the level of success in various areas, considering the constraints limiting the plant's capability. Goals or objectives should be briefly described, as well as how these goals are evaluated and changed: the regularity of checking, corrective actions to be taken, development of bench-marking activities (local, utility level, national level, international level), and motivation to reach the goals or objectives, including whether there are individual personnel motivation programmes with awards or salary adjustments.

4.1.3. Management involvement and communication

The aim of this section is to identify those actions taken by management that contribute to the attainment of goals. There are no obvious quantitative performance indicators in this area, so the discussion should be more qualitative. It can focus on three topics:

Personal action of management. This section could concentrate on how management perceives its own role in accomplishing station goals. This could include (1) being part of an improvement team; (2) acting as catalyst when required; (3) shielding employees from interference from others; (4) respecting the staff's expertise; or (5) taking an active interest in monitoring progress.

Communication with staff. This section could include the means, the content, and the reaction to communication. Means of communication can include regular meetings (weekly or monthly), cascade briefings (management to team leaders to staff), one-to-one meetings, or plant walk rounds. Content of communication should consider consistency of message, praise, encouragement and progress, or clearness of message. The description should include both communications **to** and **from** staff. Hence, management reaction to requests for help and criticism could also be considered. Effectiveness of methods of communication, the computerisation of telecommunications, and the measurement of effectiveness could also be discussed.

Relationship with staff. Management's relationship with staff can have a large effect on the ability of management to change working practices. The discussion could address the following questions: How does management relate to the staff ? What techniques are used to evaluate this?

4.1.4. Managing quality

Describe how the quality assurance (QA) programme was established at the plant and how it helps to improve plant performance. Questions that could be addressed: How did changes in QA programme affect plant performance? When was TQM (total quality management) introduced? How many persons (or percentage) were trained and licensed in TQM? How much of the plant's documentation conforms to QA requirements? The QA programme gives a tool for quality control. Applying internal audits and audits of contractors could help improve the quality of processes, components, and materials. The measures of these activities could be (1) number of internal audits; (2) number of plant audits of contractors and suppliers; (3) requirement of ISO-9000 licensing of contractors and suppliers (e.g., what is the percentage of contractors and suppliers with ISO-9000 licence?); and (4) how many plant personnel have been trained on ISO 9000?

4.1.5. Relationship with contractors

This section should comment on plant policies toward contractors. The following could be indicative of how this relationship has influenced plant availability:

- evolution of the number of employees versus the number of "permanent" contractors
- integration of the "permanent" contractors into the plant organization, for example, indicating the percentage of contract employees in the main groups: operations, maintenance, technical support, chemistry, radiological protection, training, quality assurance, industrial safety, and security
- limitations of the contractors activities, e.g. away from safety systems maintenance and tests
- requirements for the contractors, including training and QA: Does the contractor provide these?
- guidelines for the outage contractors and percentage of contractors' personnel during outages
- methods of communicating and involving the contractors with the plant management's objectives and operations philosophy.

4.1.6. Budget resources and allocation

This section should address the relationship between the allocated budget and availability performance, for example, for training, staffing, programme for major repairs or planned long outages, ageing effects control and surveillance, spare parts policy, steam generators replacement, etc. This section could also discuss the detailed budget allocation (in relation to budget requests): Is each working group informed about its own expenses and their "profitability" to the plant?

4.2. Personnel

This section comments on characteristics and qualifications of the work force and training that could influence plant performance.

4.2.1. Personnel characteristics

This subsection describes and analyses the work force and its relationship to all aspects that could affect the plant's performance or availability. It should describe the composition of the station staff as permanent plant employees and permanent or temporary contractors. The site and headquarters personnel dedicated to this plant should be identified. It could also discuss the evolution of the size of the work force (permanent plant staff and contractors).

Further, this section should identify important issues related to personnel qualification that have influenced plant performance. Among others, the following aspects can be identified:

- classification of the personnel according to their academic levels, indicating previous experience at other NPPs or industrial facilities
- stability of the staff, indicating how many people left the plant or the utility
- internal rotation programmes.

4.2.2. Personnel development and training

This section should provide an overview of personnel development programmes and training. Corporate and plant policies, programmes and practices for leadership development, career development, and rotation of personnel within and outside the plant could be discussed and how those programmes and practices affect the improvement of plant performance.

Also, this section should identify how training and re-training programmes improve plant availability. It should describe the evolution of the training programmes, training tools, how training is modified due to events, number of training courses and their attendees. It should also indicate methods to evaluate the training effectiveness. Some training indicators provided could be

- number of training hours per year
- the ratio of training budget to O&M budget
- the ratio of hours dedicated to technical courses to hours dedicated to management courses.

4.2.3. Personnel behaviour and attitudes

This section should identify measures and actions that have influenced personnel behaviour and attitudes leading to a health working environment. It should mention plant programmes that create a good working environment and how it has influenced plant performance. Some indicators could be

- safety culture courses done by IAEA or other organizations,
- self-assessment and ownership courses given,
- motivation practices,
- near-miss reports and suggestion reports.

4.3. Working practices

This section examines the working practices of all station personnel (operation, maintenance, technical support) and its effect on plant availability.

4.3.1. Plant status control

This section should discuss good practices or strengths that contribute to effective monitoring and control of plant status. A series of working processes should be discussed, such as activities to identify equipment deficiencies, reporting, labelling, documentation, including log-keeping, transfer of information on station status during the shift turnover, and the complete resolution of the detected problems. Further, the minimisation of abnormal conditions is important to insure that components and systems are able to perform their intended functions. Therefore, this section should present any management strategy, practices, or factors that contribute to minimisation of abnormal unit conditions.

4.3.2. Operations

4.3.2.1. Operating procedures

The quality of operating procedures is considered a key factor in minimising the occurrence of human related errors and ensuring a timely, effective response to abnormal conditions. This section should present good policies and practices that contribute to the quality of operating procedures. Factors could include

- policies and practices governing the preparation, review, approval, and use of procedures
- processes for procedural revisions to reflect new information, lessons from experience, and station modifications, including training on the revised procedures
- provisions to control temporary operations
- control of other supporting documents including flow diagrams, etc., that might affect equipment and system operation.

4.3.2.2. Operating aids

Operating aids are used at individual stations to minimize human error and improve operator productivity. This section should discuss the operating aids that are considered most effective to proper equipment operation. Typical examples could include

- computerized information systems
- component labelling, colour coding, marking of normal and high/low values of measured parameters, and other techniques to aid in equipment identification and operation
- provision of flow diagrams, operating instructions, cautions and warnings, failure experience, and other supporting information at field equipment location
- use of temporary or permanent locks on important equipment
- use of plastic covers on specific control panel devices to prevent inadvertent actuation and operator error
- use of checksheets for field patrols, panel status checks, and surveillance tests
- ladders, platforms, hoists, etc., that are provided for safe accessibility to equipment.

4.3.2.3. Other programs and procedures

Other elements, organizational aspects, conduct of operations, practices, and factors that affect operational activities and contribute to reliable operation could be included in this subsection or additional subsections. It could also include good features of administrative controls for operation of field equipment, such as equipment isolation for maintenance purposes and restorations to normal service.

4.3.3. Maintenance

The aim of this section is to examine how the policies, planning, and performance of maintenance affect plant availability. It should cover both outage and on-line maintenance. The case study should examine the length of planned and unplanned outages due to maintenance, considering their reduction over time or continued good performance. Reasons for this good performance could be considered under the following headings:

- **Policy** — This is the area under direct plant manager control and could include backlog clearance and the preventive-corrective maintenance split.
- **Planning & scheduling** — This would consider the monitoring and control of work both in terms of method and hardware in use, e.g., computer systems and the prioritisation of work and integration with operations, e.g., isolation of equipment
- **Procedures** — This concerns the actual instructions followed. This could include ease of use, ease of updating and correctness, recording of completion, and post maintenance testing.
- **Conduct of maintenance** — This section could consider the actual performance of the maintenance and could include quality of work, amount of re-work, and qualification of staff.

4.3.4. Technical support and other activities

This section focuses on supporting activities influencing plant availability and reliability. Plant ageing, obsolete equipment, failure rate, significant events, deteriorated radiological situation, and bad industrial safety are factors decreasing plant performance. Surveillance testing and inspection, regulatory inspections, root cause analyses of the plant's events and in-house, as well as international operational experience are the tools for identifying weaknesses. The task of engineering support is to propose appropriate corrective from these results and to manage their implementation. Case studies should present the main projects of upgrading and backfitting process in relation to plant availability.

4.3.5. Interaction between work groups

This section should illustrate and analyse the relationship between and among the different groups in the plant, including the effectiveness of communication and the methods of communication. The following topics could be discussed:

- how often the plant director or deputy director for operation visit the control room or technical support offices
- practise of organising working meetings at NPP
- practise of communication of technical support groups and maintenance group during outage
- the system of written working orders and its effectiveness
- use of interdisciplinary teams for specific tasks.

In the last few years many communication systems have been computerized. This has led to speedier communications. Comment on how these systems have helped communications in the plant between work groups.

Annex B: DUKOVANY CASE STUDY

CZ.1. PLANT DESCRIPTION

The Dukovany Nuclear Power Plant is the only operating nuclear power station in the Czech Republic. It is located in southern Moravia, the eastern region of the Czech Republic, approximately 40 km south west from its regional center, the city of Brno. Dukovany is owned and operated by the Czech Power Company (CEZ), the largest national power producer and distributor. It generates 26.4% of the company's total electricity production. In 1995, the plant contributed 20.1% to the country's total power production.

The history of construction of Dukovany began in 1970 with the signing of a preliminary agreement between the former Czechoslovakia and Soviet Union. It was followed by the 1971 decision to construct two units of the WWER-440/230 (the older type) reactors. The site preparation was started in 1974. However in 1975, the construction was interrupted and did not resume until 1978, when a decision was made to change the original plant design to four WWER-440/213 (the advanced type) reactors. Dukovany construction and commissioning took place on the following dates:

Commissioning stage	Unit 1	Unit 2	Unit 3	Unit 4
Reactor pressure vessel installation	11/1982	04/1984	02/1985	12/1985
First criticality	02/1985	01/1986	10/1986	06/1987
Connection to the grid	02/1985	01/1986	11/1986	06/1987
Nominal power achieved	03/1985	02/1986	12/1986	07/1987
Commercial operation	11/1985	09/1986	06/1987	01/1988

Dukovany consists of four identical PWR reactor units, WWER-440/213 with a rated power of 440 MW(e). The reactor coolant system (RCS) consists of six loops with one horizontal steam generator (SG) and one reactor coolant pump (RCP) per loop. The pressurizer is connected to the hot leg of either loop 1 (odd units) or loop 6 (even units). Each circulating loop, including the SG and RCP, can be isolated from the RCS by a main gate valve on either the hot or cold leg.

The reactor core consists of 312 fuel assemblies of a hexagonal shape containing ^{238}U enriched by about 2.5% ^{235}U. The reactor power and fast changes in reactivity are controlled by 37 control rods of stainless, borated steel with a fuel part in its lower half. (The fuel part is inserted into the core whenever the control rod is withdrawn from the core and vice versa.) Slow and long term reactivity changes are compensated for by injecting borated water (boric acid) into the RCS. At nominal power, the RCS pressure is 12.25 MPa with an average coolant temperature of 281C.

During normal operation, reactor power or SG pressure is maintained and controlled by the automated power controller (ARM) acting through control rod drive mechanisms. With an excessive or fast power increase the reactor is protected by a power limiting controller (ROM) and a reactor protection system (HO), which is divided into four levels ranging from stopping the control rod withdrawal (HO-4) to the reactor scram (HO-1).

The units are equipped with Engineered Safeguard Features (SZB) designed to mitigate consequences of a transient involving a fast RCS cool down or a loss of core cooling from a loss of the reactor coolant or main feedwater. To perform these operations, the plant is equipped with safety systems divided into four categories:

(1) Passive emergency core cooling system with four hydroaccumulators flooding the core in the case of a significant drop in RCS pressure.
(2) Active emergency core cooling system with three trains of a high pressure injection system (tanks and pumps) and three trains of a low pressure injection system (tanks and pumps) injecting borated water into circulating loops and the reactor on actuating the SZB.
(3) Active confinement pressure suppression system with three trains of confinement spray pumps and heat exchangers cooling the water being sucked in from a confinement sump.
(4) Passive confinement pressure suppression system consisting of twelve shallow water pools (bubbler-condensers) above each other, where the discharged reactor coolant, expanded into steam, condenses, and in case of an excessive steam pressure, the borated water in the pools overflows and additionally sprays the confinement.

To prevent a loss of main feedwater, the plant has available an emergency feedwater system with two independent emergency feedwater pumps and separate feedwater pipelines. The basic layout of RCS and safety systems of the plant can be found in attachment CZ.A1.

The electrical power of a nuclear power unit is produced by two turbine generators (TG) with 220 MW(e) each. They operate with saturated steam of 256C and 4.5 MPa at a speed of 3000 rpm. Systems and components of secondary circuit were designed, and generally produced and supplied, by Czech companies.

CZ.2. HISTORICAL PERFORMANCE

During its history, Dukovany has been continually improving its performance. Electricity generation has been stable and reliable:

TABLE 1. ELECTRICITY GENERATION (TWh)

1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
2,337	6,143	10,701	11,816	12,416	12,585	12,132	12,250	12,627	12,997	12,230

The biggest contributors to the production losses are refueling outages, which decrease the total annual production by about 20%, on average. Recently, this portion has been reduced due to improvements in outage management.

Some PRIS and WANO indicators have been selected to illustrate positive trends in plant performance as a whole or for individual units. The three charts in attachment CZ.A2 show four-year averages of the energy availability factor (EAF), unit capability factor (UCF), and unplanned capability loss factor (UCLF).

Annual values of the plant EAF are influenced by a four-year cycle of maintenance and refueling outages. This cycle is such that every fourth year an extended refueling outage takes place at each unit. At that time there is a total removal of fuel and reactor internals, as well as a series of inspections of the reactor pressure vessel and the entire reactor coolant system. To eliminate the influence of these extended outages on the EAF and to reduce other random effects, the plant's performance has been calculated as four-year unweighted means and medians of individual units' annual values. Each mean or median value given in the chart thus represents 16 EAF values of four units for the pertinent four-year period. Both the EAF means and medians rise from 1987 to 1995. The average annual increase is 0.4%. When comparing medians and means, note that means are burdened by extremely low values caused by the extended outages.

Also the UCF has been calculated as four-year means, however separately for each unit. The UCF, like all WANO indicators, has been recorded only since 1990. The biggest annual increase in UCF was achieved at the Unit 1 (0.6%). Unit 2 has had the lowest annual increase, as well as the lowest absolute values. This has been due to the extremely low UCF value in 1992, when an extended outage took place, during which some upgrading activities were carried out. So a significant improvement in performance is expected. The median of all units' UCF values from 1990–1995 is 84.2%, while their mean is 82.2%.

The UCLF is presented in the same way as the previous two indicators. The best performance was again achieved at the Unit 1, where the annual decrease has been 0.55%. A slower, yet still decreasing trend, can be seen at the other units. The median of the UCLF values between 1990–1995 was 2.6%; their mean was 2.9%.

The three safety indicators presented in attachment CZ.A2 are the number of reactor scrams, the number of INES events rated higher than 0, and the number of human errors. First, the number of reactor scrams in the first three years of operation was marked by the commissioning of individual units. After this early period, the situation stabilized. Between 1990 and 1995, the annual average was 0.5 scrams per unit. Remarkable results have been achieved at the Unit 1, where no reactor scram has been recorded since 1992. Second, there is no apparent trend in the INES event indicator. The number of INES 1 events, however, is steadily low with an average of 1.2 events per unit per year. During the entire history of the plant, only one INES level 2 event occurred — a loss of off-site power (this was the most serious event at the plant through 1996). Third, due to the high personnel qualification, the number of human-factor-caused events remains relatively low with a declining tendency. With the increasing portion of contractors, however, the number of events caused by contractor's personnel has also risen. These low numbers of reactor scrams, significant incidents, and human errors have also contributed to the high plant availability and its reliable and safe operation.

CZ.3. OVERVIEW OF THE DUKOVANY CASE STUDY

Several factors have contributed to the high availability of Dukovany. The most important contribution is its team of highly qualified, devoted, and responsible professionals. The management attempts to maintain this high level of performance and identify problems that might adversely affect plant performance. To receive independent evaluations and views, the plant actively participates in many of the international programs aimed at improving performance. To increase the level of plant technology,

- many upgrading projects have been implemented to eliminate existing deficiencies,
- the management has improved plant operating and administrative procedures,
- a QA system has been widely implemented,
- the level of personnel qualifications has been kept high through the educational and training system, including regular examinations,
- there has been a steady improvement in internal communication and in creating a pleasant working environment, and
- international experience exchange through the IAEA and WANO channels.

All these efforts by the entire plant staff have resulted in its successful operation with a high and steadily improving level of availability, reliability, and safety. These efforts have resulted in Dukovany being one of the best-operated plants in the world.

CZ.4. MANAGING AND WORKING AT DUKOVANY

CZ.4.1. Management practices

CZ.4.1.1. Organizational structure

Dukovany is an organizational unit of the operating utility, CEZ. The plant's organizational structure is divided both vertically and horizontally. The vertical structure is formed by two managerial levels: (1) top management (directors and deputy directors) and (2) departments (specialized executive units). The departments are further divided into sections. The horizontal structure consists of sectors (activity areas) managed by a deputy director. A chart of the organizational structure can be found in CZ.A3.

The plant directors are directly responsible to the utility executive board. The technical director is responsible for technical management (operation, nuclear safety, and maintenance). The finance director manages the finance and administrative areas (business and personnel matters and services). Each of these two directors has deputy directors responsible for the individual sectors. The deputy directors for nuclear safety, operation, and maintenance report to the technical director. The other two deputy directors report to the finance director. Each deputy director manages a sector, vertically divided into departments. Sections perform the tasks of the department. The heads of each of these organizational units are responsible for their unit's performance.

The plant management has available the following organizational tools:

- Director's orders and decisions
- Management standards (regulations, rules, programs)
- Guidelines (management procedures or methods) at the level of top management
- Quality handbook
- Program procedures at the level of sections
- The management meeting, quality committee, emergency team, and other advisory boards, committees, and working teams

A series of organizational changes occurred from 1990 to 1995. In the first stage, 1990–1993, the original Soviet organizational model was transformed to unite the maintenance and system engineering departments into one section. In the second stage, since 1993, the maintenance department sections (I&C, electrical, and mechanical) were transformed into private companies. The main objectives of this privatization were (1) to reduce the number of permanent employees at the plant, (2) to better use the maintenance potential in the time between refueling outages, and (3) to improve the quality of work by contracting it on a commercial basis. The privatization transferred maintenance costs from fixed costs to variable ones. Economic benefits of the privatization, however, have been mixed.

CZ.4.1.2. Management involvement and communication

The plant management is actively involved in improving plant performance. Three areas of management are discussed.

Membership in international organizations. After the political changes in 1989, the plant started participating more actively in international organizations, such as WANO and IAEA. Since that time, the plant has developed international co-operation, has established contacts with western nuclear power plants, and has been participating in a number of PHARE projects. In connection with accepting the western experience and standards, management has improved the plant's safety culture and level of performance.

Improvements in the working environment. Another important factor affecting plant performance is the working environment. During the 1990s, management has succeeded in maintaining a high level of housekeeping at the plant. Many buildings and offices, including operator rooms, have been refurbished: equipped with computers, new furniture, and other facilities (microwave ovens, coffee makers, etc.). The grounds around the plant have been landscaped and the overall appearance of the plant has significantly improved. Also, a plant security system was established that significantly improved plant security.

Plant communication. To facilitate the everyday communication of plant personnel an email system on the plant's internal computer network (LAN) has been implemented. The system is used extensively by the staff. It has enabled quick and effective communication between the plants operated by CEZ that are interconnected by CEZ-net.

Plant management uses various tools of communication. Every Monday, plant directors meet with their deputies, plant spokesmen, and other invited guests in the **management meeting**. On the following day, the deputy directors meet with the heads of their departments, who meet with their section heads and team leaders on the same day or Wednesday. The meetings take place during working hours and usually last from 30 to 60 minutes. They are the main source of information obtained by the staff from the management.

To communicate personnel's views to the management, **working information meetings** have been introduced. They are held once every three months on the level of department or shift. Another way of communicating staff's views and ideas to the management are various questionnaires prepared by the department of internal communication. The plant management also arranges various informal meetings with the plant staff either in the form of discussions taking place once or twice a year, or in the form of the new years reception, the prestige ball, or at Dukovany day, where the plant employees meet each other and their relatives.

To keep the plant personnel informed, the department of internal communication publishes an internal newspaper, Atomix, twice a month. Articles in this newspaper are prepared either by the department itself or are provided by plant staff. Topics include practically all areas of plant activity: new investment projects, operational performance indicators, intended changes, questions and answers, sporting and cultural information, etc. All important organizational information, as well as brief news are displayed on light-boards in the dining hall during breakfast, lunch, and dinner. In addition, a newspaper monitor focusing on industry news is prepared every day and posted on a notice-board in the administration building's entrance hall.

Also, significant improvements have been achieved in public relations. A new information center has been built at the plant with a high quality presentation of the plant, its policy, and effects on the environment to the public. A more open and friendly attitude toward the surrounding towns and their representatives has helped in gaining their confidence. For example, the public consented to the construction of an interim spent-fuel-storage facility on the plant site in 1994. This was obtained by the plant management after long negotiations with local authorities and headed off a threatened closure of the plant because of a lack of spent-fuel storage capacity.

CZ.4.1.3. Managing quality

The quality control system was introduced at the plant between 1991 and 1996. About 300 plant employees have been trained and licensed in ISO and NUSS Standards and TQM principles. The plant has been performing internal audits since 1991; approximately 10 internal audits per year have been carried out. Since 1995, the plant has been performing external audits of contractors and 52 plant contractors and suppliers have been audited. The ISO 9000 licence requirements for contractors have not been established yet. For the time being, however, about 20% of contractors are ISO 9000 licensed.

CZ.4.1.4. Relationships with contractors

One plant policy is to reduce number of permanent employees and to increase the involvement of contractors in various plant activities (investment projects, maintenance, engineering services, cleaning, etc.). The contractors have not been integrated into the plant's organizational structure. Because some of the contractors are privatized plant departments, their staff is highly qualified, trained, and experienced. In addition to high quality standards for contractors, the plant requires a license and QA handbook. Regular audits of the contractors are performed by the plant. There are no limitations on the contractors' activities. There are no special guidelines for the outage contractors, they must comply with the plant regulations. Up to 95% of personnel performing outage tasks are on the contractors' staffs.

The plant communicates its objectives and operation philosophy to the contractors on training days. In addition, the contractors are provided with all the above mentioned management standards, orders, decisions, guidelines, and regulations. However, it is the contractors' responsibility to provide adequate training to their employees and to establish their own QA Programs, including staff training. For these purposes, the contractors can also use the utility's educational and training centre in Brno on a commercial basis.

CZ.4.2. Personnel

CZ.4.2.1. Personnel Characteristics

Table 2 shows the number of permanent employees during the 1990s with the aforementioned organizational changes. It also shows the power productivity per employee.

TABLE 2. NUMBER OF PERMANENT EMPLOYEES

	1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**
Number of permanent employees	2754	2580	2475	1972	1819	1763	1719
MW h per permanent employee	4570	4702	4950	6403	7134	6937	7475

Table 3 below illustrates the staff composition in 1996 in terms of Dukovany employees and permanent contractor employees. There was been a significant rise in the total number of employees at the plant since 1990, i.e. prior to the privatization. Note, however, that the 1996 contractor data include contractor employees before the privatization (e.g., turbine-generator or large equipment maintenance during refueling outages) who are not included in the 1990 employee data.

TABLE 3. DISTRIBUTION OF EMPLOYEES

Year	**1996**
Contractors' employees	2656
Plant employees,	1719
Non-technical	590
Technicians	1129

Table 4 shows the educational levels of the plant staff. There is a positive trend in this indicator represented by a decrease in the number of workers with a basic education and an increase in the portion of university educated personnel. This high level of education is one of the important factors influencing the plant availability. The licensed reactor operators and senior reactor operators, for example, are required to be university-educated engineers. Except for the education requirements, the personnel must be in good physical and mental condition, which is checked by a medical and psychological examination when starting the job. The medical examination is repeated annually; the licensed operators, in addition, must pass psychological tests every two years.

TABLE 4. EDUCATIONAL LEVEL

	1993	**1994**	**1995**	**1996**
Basic education	2.3%	1.9%	1.4%	1.1%
Apprenticeship	33.3%	34.1%	24.8%	23.6%
Secondary education	40.1%	36.9%	46.6%	47.1%
University	24.3%	27.1%	27.2%	28.2%

CZ.4.2.2. Personnel development and training

The plant has established a comprehensive training program divided into basic and refresher training. The training takes place at both the utility's Educational and Training Center in Brno and at the plant.

Basic training is composed of six specific categories set up according to individual plant professions (managers, licensed operators, system engineers, foremen, equipment operators, etc.). Each particular training program consists of training modules (theoretical education, practical training at the plant, simulator training, preparation for a final exam, etc.). The β-category training for licensed operators, for example, consists of 10 modules, lasts for 66 weeks, and is completed by a final exam and a month of on-the-job training, The operators take a state exam to obtain a licence.

A large part of the operations personnel's **refresher training** is the program of regular training days. During these training days, main plant modifications, procedure changes, and operational experience feedback are communicated. The frequency for each operations staff member is one training day per six weeks. The other plant personnel's training days take place with a lower frequency. Licensed operators also complete a week of refresher simulator training once every six months. Other selected staff members (electricians, crane operators, welders, etc.) complete various specialized professional refresher courses. The plant personnel is annually trained in the fire protection and industrial safety. Managers and other selected personnel participate in management courses and QA training. Also, many employees take part in foreign-language and computer courses.

For historical reasons, the full-scope plant simulator for the WWER-440 reactors in the former Czechoslovakia was built at the NPP Research Institute in Trnava, Slovakia, near the Bohunice plant. Therefore Dukovany licensed operators must go there to complete their required simulator training. Since 1994, however, a development program has been in progress at the Dukovany plant with the objective to establishing a full-scope simulator of the plant.

The recognition of importance of high level of personnel training and education by the plant management has been expressed by increased resources allocated to this area as indicated by Table 5.

TABLE 5. TRAINING AND EDUCATION RESOURCES

	1990	**1991**	**1992**	**1993**	**1994**	**1995**
Average training and educational expenses per employee (CZK, thousands)	2675	2955	3452	4829	7630	10365
Training budget as a percent of the O&M budget		0.24%	0.28%	0.29%	0.33%	0.45%

Although there has been a continuous increase in the training budget, the ratio of the training budget to the O&M budget is relatively low when compared to the industry. It is influenced by Dukovany's accounting and budgeting practices that do not include the other expenses (traveling, housing, catering, salaries) associated with training and education.

CZ.4.2.3. Personnel behaviour and attitudes

Personnel behaviour and attitudes are considered to be one of the most important factors contributing to the high plant availability. Due to very careful selection of personnel and relatively long and demanding training process, only quality individuals can successfully complete all the tests and exams. In addition, the successful candidates obtain very solid and broad knowledge of the plant and thus develop a feeling of responsibility and ownership toward the entrusted equipment. It is only natural that equipment operators, electricians, and I&C technicians are not narrowly focused just to their own problems but also notice the other equipment and report to each other the deficiencies or faults discovered on their walk-rounds.

CZ.4.3. Working practices

CZ.4.3.1. Plant status control

The basic method of plant status control is walk-rounds. In the main control room (MCR) licensed operators, besides continuously monitoring equipment, carefully check all gauges, displays, alarms, and control lamps every hour and manually write down selected plant parameters into parameter record sheets. Once a shift, they visit and check the emergency control room and reactor operators also walk through the reactor control and protection system rooms adjacent to the MCR. The equipment operators, electricians, and I&C technicians check their equipment every two hours. They check for any anomalies or deficiencies and write down selected important parameters.

If the staff discovers a problem, the staff member (MCR or equipment operator) reports it to a responsible operations foreman, who prepares a work request, which is then forwarded to a responsible maintenance coordinator. He prepares a clearance sheet indicating the boundary of clearance, tagouts, and equipment to be de-energized. The clearance itself is then implemented by operations personnel. Once the clearance implementation is confirmed by the responsible operations foreman, the coordinator assigns the work to a specialized permanent contractor and keeps track of the subsequent activities until the clearance is removed and the repaired equipment is returned to operation. All the necessary information is entered, transferred, and confirmed via the coordination LAN. Also, MCR operators record all clearances in their log books and transfer the information at a shift turnover to the coming shift. MCR operators also record all de-energized components in the power operated equipment card file. Operations foremen and senior reactor operators have access to the coordination LAN to regularly obtain information about the current status of all active clearances.

Another way of monitoring plant status is regular surveillance tests of safety systems and tests of system automatics and protections. These tests are performed according to an approved schedule, mainly on a monthly or quarterly basis. Safety system status (component position) on completing the test is checked by using check lists to make sure that the system had been properly returned into a standby position.

A minimum of lighting alarms and annunciators is the sign of the normal and safe plant operation. Therefore, the plant policy is to minimize the number of permanently lit alarms, which has been established as one of the minor upgrading projects. Once an alarm actuates, the control room operator sends a field operator to the spot to determine the cause. Then appropriate measures are taken to clear the alarm or to solve the problem.

CZ.4.3.2. Operations

CZ.4.3.2.1. Operating procedures

Most of the current operating procedures have been adopted from the Former Soviet Union or the Bohunice V-2 plant and translated. A majority of them have been revised and amended several times. The revisions and amendments are performed by the operational mode section, where all information of plant modifications, lessons learned from the operational experience and operators' comments are collected and included in the procedures. As they are in a book form, even with "loose" pages, it is often quite difficult to implement the amendments or revisions without affecting the procedure format. For these and other historical reasons, the procedures have been written in various styles, formats, and with different approaches. They are not strictly divided according to the units, although differences exist between the units.

The currently valid procedures are not symptom oriented, processed as a continuous text without exact step-by-step manipulations and are usually not suitable to be used directly for equipment manipulations. These drawbacks are being compensated for by the high level of plant personnel qualification, knowledge, and education. This situation has been improving since 1994, when the plant procedure upgrading project was started. In connection with it, a guideline for development, approval, distribution, and updating of operating procedures, operating programs, and operating instructions was issued and the following actions were taken. Since 1994, a team of experienced operations personnel backed by Westinghouse professionals have been developing symptom-oriented emergency operating procedures.

In 1995, 19 of the most important normal operating procedures were selected for upgrading. A team of qualified operations and engineering personnel have been established to develop the new procedures. A new methodology for developing the procedures was prepared by the operational mode section. The narrative, explanatory part of procedures was developed by system engineers, while licensed operators prepared the manipulation sections.

In 1994, 1995, and 1996, all operating flow diagrams were transformed into digitized form and processed by computer graphics. Comments on errors, deviations, and differences between the actual state and the diagrams are being collected from operators and passed to system engineers, who check, process, and approve them. They also provide input on all plant modifications influencing the flow diagrams. All this information then proceeds to a reference workstation, where all procedure revisions and amendments are performed and incorporated into the diagrams. A similar situation exists for the power supply sources database, which is regularly checked and updated by electrical engineers.

CZ.4.3.2.2. Operating aids

A variety of operating aids are used at the plant, both in the MCR and at the field equipment locations. The MCR operators are supported by colour coding of safety system panels. The SI pump and RCP control switches are covered by transparent plastic boxes. Protection covers are placed also on the turbine and generator trip buttons. All equipment control switches are grouped and colour coded according to individual systems. Simplified flow diagrams with green, red, and white lamps are provided on a board above system control panels helping operators to quickly check the plant status as to the component operation and position. Field operators are aided by pipeline colour coding (red strips on steam pipelines, grey — demineralized water, green —service water, blue — service air, etc.). All components are consistently labeled by firmly attached metal plates containing a unique component code, arrow-shaped plates attached to pipelines indicate flow direction and kind of medium (water, condensate, etc.). All permanently secured components (open or closed valves) are locked and tagged. Electricians are equipped with special insulated ladders to work on control room or switchgear room panels. They use new high voltage testers and shortcircuiting devices.

All plant workplaces are equipped with computer workstations (PCs) connected by a local area network (LAN). This local network is connected to superior CEZ network (WAN), which enables communication with other CEZ plants. Individual operation sections have developed specialized applications (a shift supervisor information system giving updated information of plant parameters; an operator support system guiding operations during transient; and chemical, radiological, and I&C systems, etc.). These will be included in an integrated plant information system being developed by CEZ.

CZ.4.3.3. Maintenance

CZ.4.3.3.1. Maintenance policy

A plant maintenance policy has been derived from the overall strategy of the CEZ and is being regulated by both international and national standards. The strategy is to operate with a minimum number of outages that are as short as possible. It is based on methods of predictive, preventive, and corrective maintenance. Material and financial plans of maintenance come directly from this policy. They are divided into long-term (five-year), one-year, monthly, and daily plans. Planning and work management is supported by a Hewlett-Packard information system adapted to plant's conditions and six levels of urgency are used to prioritize work.

The maintenance program as conceived implies that a majority of work is carried out during refueling outages. This serves the purpose of work planning and management, but limits the potential for reducing the length of refueling outages, another objective of maintenance management and coordination.

Some recent basic maintenance indicators are

Specific production costs	330 CZK/MW(e)
Specific maintenance costs	60 CZK/MW(e)
Number of plant employees per installed MW(e)	0.98
Number of plant employees + average contractors per MW(e)	1.4
Refueling outage length	42.0 days
Extended refueling outage planned length	72.0 days
Refueling outage average length	49.5 days
Preventive (predictive)/corrective maintenance ratio	1 to 1

One of the frequent problems in maintenance performance is a high portion of work orders postponed or not completed for a long time. Table 6 shows a positive trend in maintenance backlog clearance as a percent of issued work orders that have been completed on schedule. (A work order is completed on schedule if all its tasks are performed on schedule; there are two tasks per work order on average). The backlog clearance is an important indicator of maintenance management efficiency. A high ratio of promptly completed work orders positively influences plant availability.

TABLE 6. MAINTENANCE BACKLOG

	1990	**1991**	**1992**	**1993**	**1994**	**1995**
Portion of issued work orders carried out on schedule	33.1%	33.4%	26.4%	36.0%	45.0%	56.9%

CZ.4.3.3.2. Maintenance planning and scheduling

For the maintenance planning, a computer system, "maintenance management," based on a Hewlett Packard product has been developed and introduced. The system is used for work order management and administration and consists of several modules. The equipment catalogue module contains all equipment data (technology, safety issues, etc.) and includes some submodules (equipment maintenance history, equipment preventive maintenance planning, etc.). The work order management module contains standard work orders (templates for recurring activities: equipment inspection, diagnostics, overhaul, or replacement) and induced work orders (manually generated upon realized needs). Both the induced (active) and standard work orders (when activated) must receive approval. On approval they leave the "maintenance management" system and enter the "coordination network," a LAN-based maintenance scheduling system. Its FoxPro-based software enables detailed activity scheduling, an integration with operation, and an optimization of activities according to the available capacity. The network serves as a means for entering and sharing information about clearance implementation or removal. This information is transferred to a "daily maintenance plan" containing detailed information of a particular day's maintenance activities. It is used for opening and closing a work order and for efficient communication between coordination and maintenance staff, enabling flexible changes in scheduling according to the available capacities.

CZ.4.3.3.3. Maintenance procedures

Contractors performing maintenance are required to use work procedures (both the plant's and their own approved by the plant), but a consistent system of work procedures has not yet been established. However, the plant has been implementing a common database system for the development and administration of the work procedures since 1995. This system is also accessible from the maintenance management system. Simultaneously, a consistent policy regulating development, approval, and revisions of work procedures is being prepared.

The plant maintenance transformation since 1990 has led to positive changes in the performance of maintenance. Privatization of the plant maintenance departments has provided the plant with an effective economic tool for ensuring high quality services. Quality of work and the contractors' staff qualification and industrial safety is kept high or improves by demanding requirements imposed on the contractors (i.e., QA Programs, ISO licences, plant access requirements, etc.).

CZ. 4.3.4. Technical support and other activities

After the political changes in former Czechoslovakia in 1989 and due to increasing requirements of the international community to revise and improve safety of nuclear power plants of Soviet design, Dukovany started its upgrade program. Its "zero" stage, called "plant completing," began in 1986 as a response to the Chernobyl accident and was based on a government decision No.309 of 20 November 1986. A prerequisite of successful program implementation was to evaluate the Dukovany's design, to identify weaknesses, and propose adequate solutions This was done using the following sources of information:

- IAEA missions: (1) an OSART mission in September 1989 focused on the plant's operation, (2) a Re-OSART mission in November 1991 focused on the plant's maintenance, and (3) an ASSET mission focused on operating experience feedback
- information received through WANO information exchange programs
- joint activities with other WWER-440 plant operators ("WWER-440/V213 Club" and "Users Group")
- plant audits: (1) an internal audit was performed at the plant in 1994 to evaluate the plant design from the point of view of the plant's nuclear safety and reliability, availability, maintainability, lifetime, and spare parts procurement and (2) an external audit performed by the ENAC consortium evaluating the plant's design from the standpoint of international standards
- supporting analyses, IAEA and PHARE projects: (1) PSA study (level 1) completed in 1995, (2) IAEA Consultants Meetings in 1994 and 1995; (3) IAEA program "Safety Assessment of WWER-440/V213 plants" with the Bohunice V-2 as the reference plant, and (4) results of equipment qualification assessment, etc.

As a result of the above missions and assessments, their findings and recommendations, the following areas of problems and weaknesses were identified

- The design of WWER-440/213 plant differs from the designs based on IAEA standards, which can adversely affect the potential for continuing safe operation and life extension.
- There might be limits on component life due to their overall reliability and maintainability.
- Limited availability of spare parts and frequency of their need could adversely affect plant availability.

– Obsolesce of some components may require their replacement.

Based on these conclusions, the main objectives of the plant upgrade project are

- to modify the plant technology according to the current requirements considering prospective licence renewal
- to upgrade the obsolete plant equipment and structures to prolong their operability, reliability, and maintainability
- to make the operation of all plant units possible through their designed lifetime and create conditions for the life extension
- to facilitate a cost effective increase in rated reactor power

To achieve this, a comprehensive project has been developed. It has been divided into the following four stages:

Stage 0 (Zero) — Plant completing program (1986–1995)

A substantial part of this program comes from the surviving activities of the efforts following the Chernobyl accident. They have been complemented by later individual projects developed to solve urgent problems as identified from everyday operational experience. A number of problems have occurred during regular testing programs. The particular trends are shown in the following Table 7.

TABLE 7. TRENDS IN NUMBER OF EVENTS

	1990	**1991**	**1992**	**1993**	**1994**	**1995**
Portion of events revealed during testing	19.8%	49.2%	33.3%	45.0%	42.5%	44.0%
Number of control rod drops due to a drive mechanism failure	12	10	3	4	4	1
Number of circulating water pump failures	18	18	10	8	9	6
Unavailability of high pressure injection system	0.050	0.023	0.008	0.0120	0.008	0.005

Most of the activities in the framework of the **Zero** stage have been already completed and have contributed to improving reliability of plant components as indicated in (1) a decrease in control rod drops, (2) a decrease in circulation water pump failures, and (3) an increase in the high pressure (HP) injection system availability.

First, the significant decrease in the number of dropped control rods due to drive mechanism failures after 1991 is due to installing two standby power supply converters. Frequent failures of these converters were causing a loss of braking voltage to the control rod drive mechanism (CRDM) with a subsequent drop of the associated control rod. With the modification, the standby power supply converter automatically takes over the power supply of a CRDM as soon as its associated converter fails, and the rod is held in its position until the failed converter is replaced. As the control rod drop requires an unplanned reactor power reduction at least by 15%, this modification has positively influenced plant availability.

Second, the decrease in number of circulating water pump failures, which directly influences the plant availability, resulted from modifications performed at the pumps. I&C equipment modifications implemented in 1990 and 1991, as well as the installation of a new control system SAIA in 1992, lead to a reduction of the failure rate by more than three times during the 1990s.

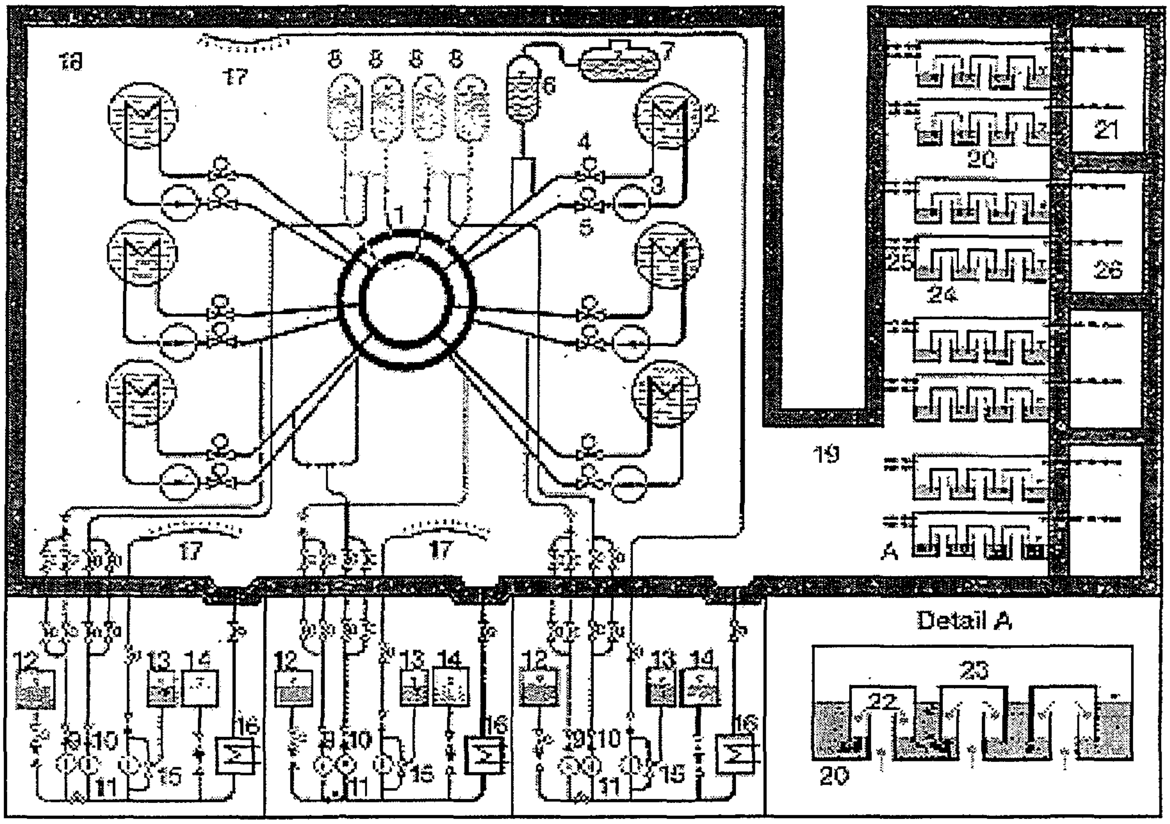
Third, because of several modifications performed on the high pressure injection pumps (which were the major contributors to the system unavailability) a significant drop in high pressure injection system unavailability occurred in 1991 and 1992. These modifications included: replacement of check valves in pumps' suction piping, replacement of motor pump shaft coupling, design, and material modifications of a hydraulic balance disk (pump axial force compensating device) and amendments to pertinent operating procedures. (For more information regarding these modifications, please refer to the WANO Good Practice GP MOW 95-002 issued by the WANO Moscow Center on March 20, 1995.)

Because the following stages are projected for the future, they are mentioned only briefly.

Stage 1 — Urgent Actions (1996–1999): This part of the upgrading project involves implementing various partial projects proposed as necessary by plant departments as a result of technical self-assessment and regulatory body requirements.

Stage 2 — Plant upgrading (2000–2006): During this stage, actions based on requirements, recommendations, and suggestions following the above mentioned missions, assessments, and audits will be done. The goals of this stage are (1) to keep and increase nuclear safety, (2) to decrease operating costs (with a power uprating), and (3) to begin plant life extension.

Stage 3 — Lifetime extension (2007 – 2010, or 2016): Activities of this project stage are aimed at plant life extension and could include replacing some key components coming to the end of their lifetime.



1. Reactor
2. Steam generator
3. Reactor coolant pump
4. Hot leg main gate valve
5. Cold leg main gate valve
6. Pressurizer
7. Bubbler tank of pressurizer
8. Hydroaccumulators
9. ECCS high pressure injection pump
10. ECCS low pressure injection pump
11. Confinement spray pump
12. HP ECCS borated water storage tank
13. Hydrazine hydrate storage tank
14. LP ECCS borated water storage tank
15. Ejector
16. Spray system heat exchanger
17. Spray system nozzles
18. Confinement
19. Interconnecting corridor
20. Bubbler-condenser (water pool)
21. Non-condensable gas holder
22. Bubbler-condenser steam inlet
23. Bubbler-condenser steam space
24. Bubbler condenser tower
25. Special self-locking check valve
26. Plain check valve with dampers

FIG. 1. RCS and safety system layout.

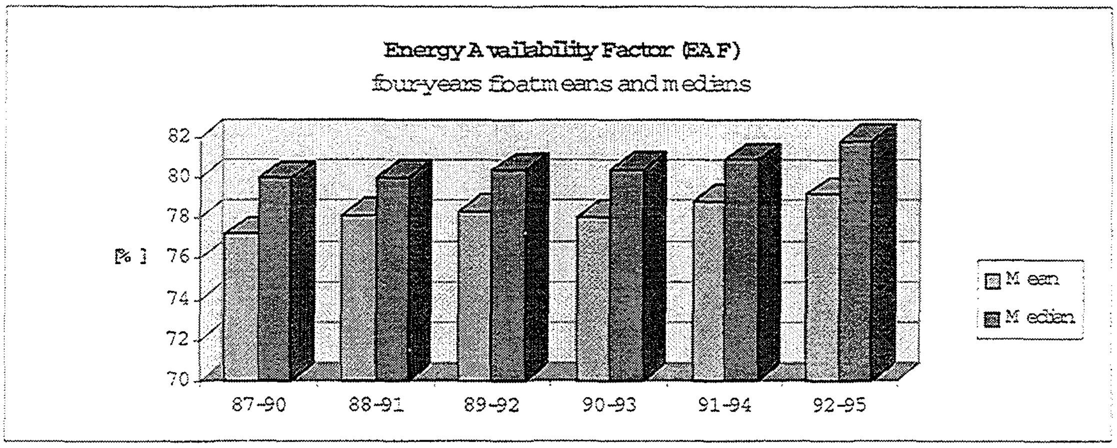


FIG. 2. Energy availability factor.

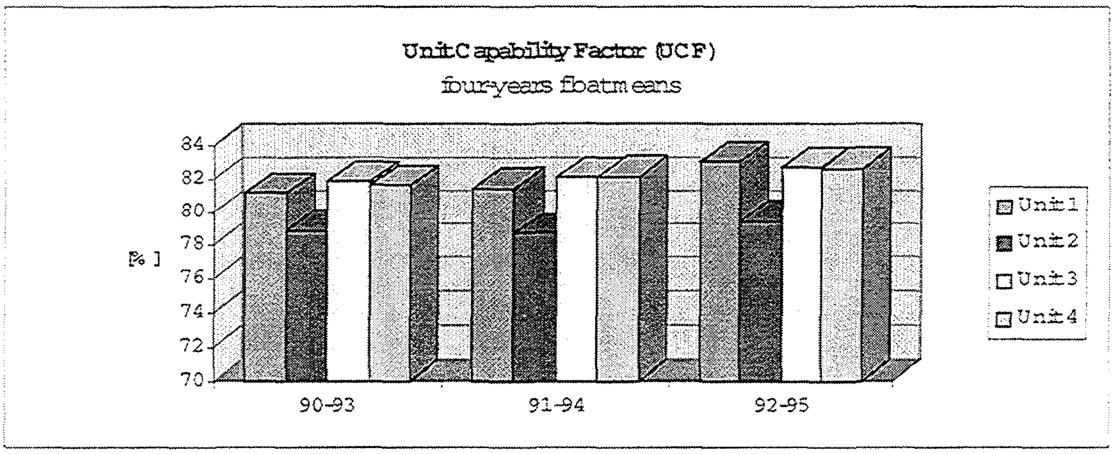


FIG. 3. Unit capability factor.

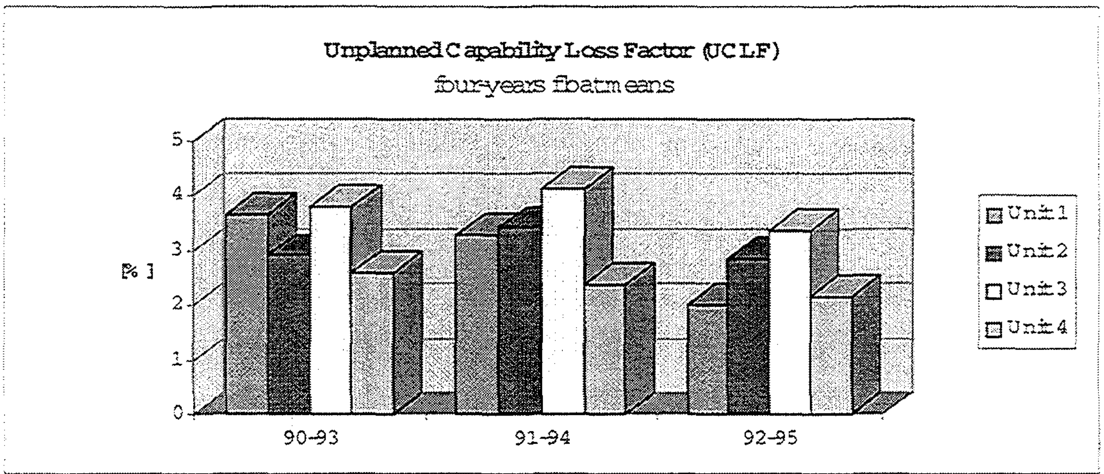


FIG. 4. Unplanned capability loss factor.

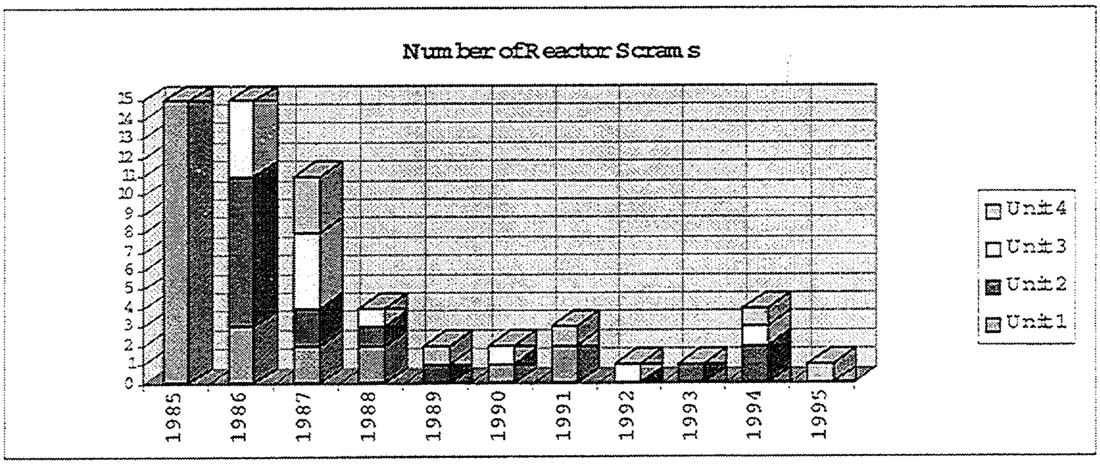


FIG. 5. Number of reactor scrams.

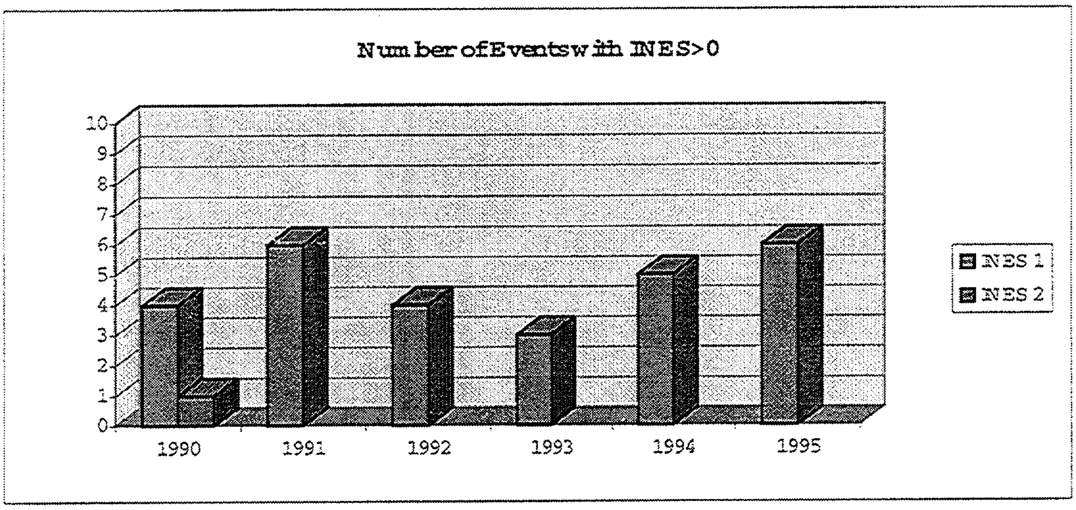


FIG. 6. Number of events with INES>0.

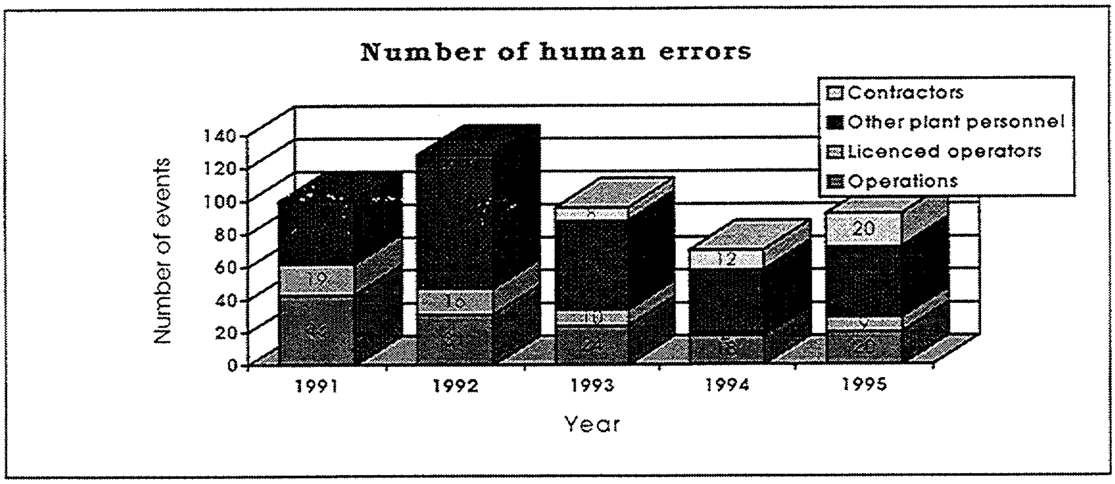


FIG. 7. Number of human errors.

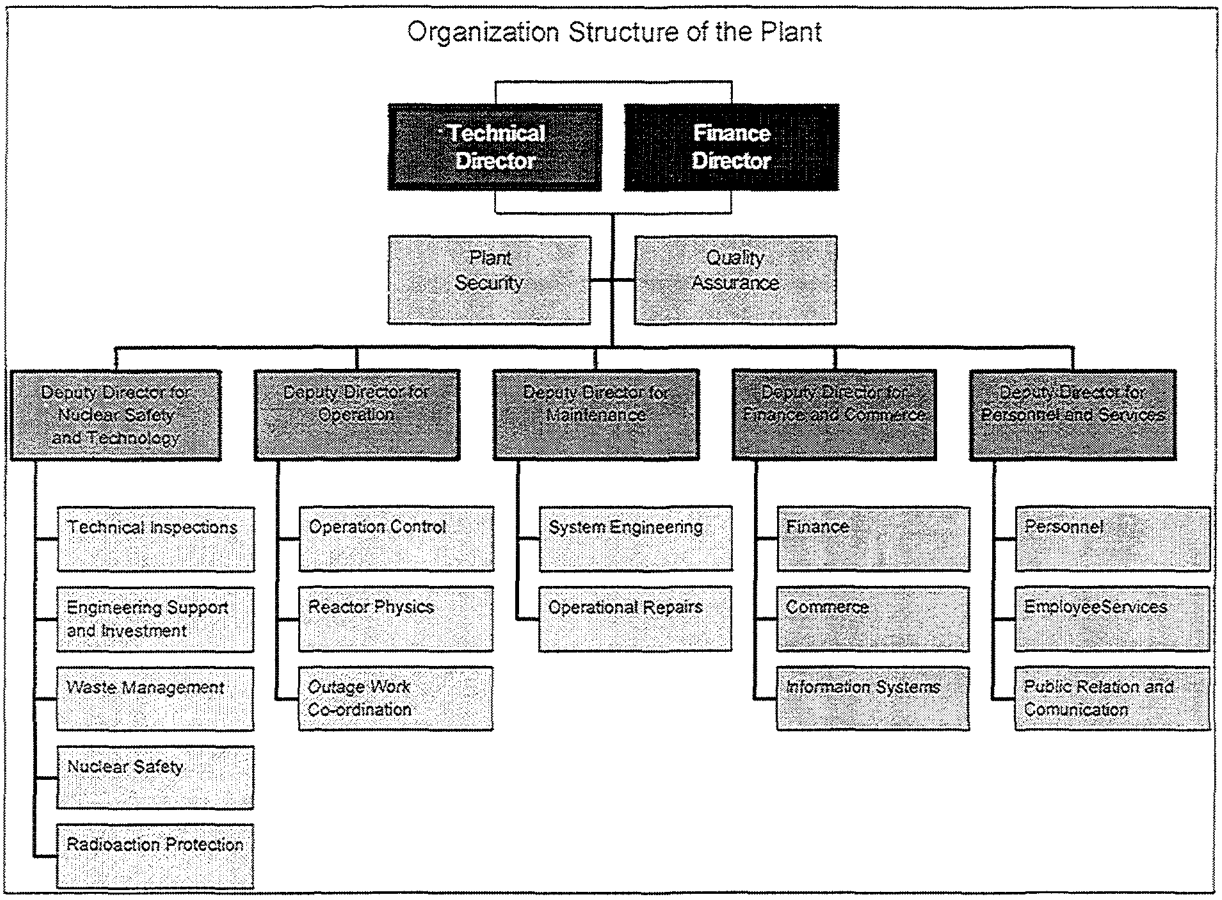


FIG. 8. Organizational structure of the plant.

Annex C: BLAYAIS CASE STUDY

FR.1. PLANT DESCRIPTION

The Blayais NPP is located in the Gironde region of France, 60 km north of Bordeaux on the right bank of the Gironde Estuary. It is a typical example of the PWR system installed throughout France. It has four identical units, each with a capacity of 910 MW. Approximately 25 billion KWh of electricity are produced annually. The commissioning dates of the units were:

Unit 1	Unit 2	Unit 3	Unit 4
12/1981	02/1983	11/1983	10/1983

The enormous volume of water in the Gironde Estuary represents a flow rate of 20,000 m3/s; thus it was not necessary to build cooling towers. However, this did call for constructing water intake and discharge connections in the river. The water is heated by 10°C in the power plant-cooling system. To respect the environment, a local government law addresses the temperature of liquid releases in the Gironde. The temperature limit in July and August is 36.5°C and the average monthly temperature limit is 33°C for the summer months. So, power decreases are required in summer when the Gironde water temperature is above 25°C. This is the case several days per year.

FR.2. HISTORICAL PERFORMANCE

The availability and unavailability factors are presented in Tables 1 to 6.

Table 1 presents some of the PRIS indicators.

TABLE 1. ANNUAL ENERGY AVAILABILITY AND UNAVAILABILITY FACTORS

	1990	1991	1992	1993	1994	1995	1996
Energy availability factor (EAF) percent	78.1	80.1	77.9	87.9	78.9	84.0	87.8
Planned unavailability factor (PUF) percent	4.8	4.1	3.1	1.2	3.8	0.4	0.0
Unplanned unavailability factor (UUF) percent	1.2	0.8	2.1	0.7	1.2	0.4	1.4

The total availability of the Blayais site reached 84% in 1995 despite a ten year outage and an extra shutdown of Unit 3 to check the steam generators support plates. This represents an increase of 6% from 1992. Good availability has been the result of two major elements: (1) controlling the direction of outages and (2) the very low unplanned unavailability factor. First, the duration of outages has been controlled. This is one of the strong points of Blayais. In 1995, on average, each outage only exceeded the planned duration by 1.2 days. This is a decrease of 3.5 days from 1992 (when it was 4.7 days). This good result was also obtained in 1996, when durations were less than planned durations. Second, there has been a significant improvement of the unplanned unavailability factor from 2.1% in 1992 to 0.4% in 1995. The slight increase in 1996 is due to defects on electrical equipment.

Some of the highlights are summarized in Table 2:

TABLE 2. OTHER PERFORMANCE INDICATORS

	1990	1991	1992	1993	1994	1995	1996
INES significant events	9	5	3	7	3	6	2
Unplanned automatic scrams	2.62	1.69	1.38	2.05	1.02	2.06	2.69
Industrial safety accident rate	12.2	8.2	5.7	7.8	8.5	5.7	10.5
Collective dosimetry	3.08	3.39	3.31	2.63	2.83	2.37	1.82

As seen in Table 2, there have been few INES incidents, but there has been little progress in decreasing unplanned automatic scrams. In 1996, it was mainly electrical equipment defects and external causes that provoked these scrams (e.g., clogged rotating drum screens).

Regarding the industrial safety accident rate, this rate exceeds plant targets. Further, there has been one EDF accident for every six contractor accidents. Detailed analysis does not show a single major cause of these accidents. Therefore, there appears to be a general lack of the industrial safety. Only a change in industrial behaviour at the work sites could reduce the number of accidents.

Also, there has been a significant improvement in collective dosimetry results (13.25 mSv in 1992 down to 9.49 mSv in 1995). This has been mainly due to management initiatives and involvement of workers in ALARA initiatives. The results in 1995 take into account a ten year outage and the replacement of two vessel heads. In 1996, two particular operations influenced the collective dosimetry. These were the replacement of a vessel head and of pressurizer heaters. Finally, hotpoints in Units 3 and 4 still require cleaning.

FR.3. OVERVIEW OF THE BLAYAIS CASE STUDY

EDF recognises that overall NPP performance is based on both efficient safety and high availability, and many factors contribute to both aspects. Although Blayais is a part of the French 900 MW series and benefits from the standardisation of design and of manufacturing components, the main effects of standardisation are strong headquarter competencies to help top management of Nuclear Generation Division and the nuclear sites to conduct changes, to anticipate and develop responsiveness, to reinforce high levels of expertise, and to master the technology and its control. Therefore,

- Specific resources are devoted to preparing and implementing top management decisions. In practice this leads to helping the definition of main technical and management directions and strategic control implementation for the validation of the plant's strategic plan;
- Centralised engineering implements common references in relation to local engineering to identify solutions to solve major technical problems and support sites in outage activities;

- Reliability centred maintenance is co-ordinated by headquarter's departments with multidisciplinary teams on sites to carry out efficient preventive maintenance programmes;
- Through experience feedback reports and data base analysis, centralised engineering identifies average term problems and proposes adapted solutions, such as equipment modifications or organizational changes;
- Furthermore, some operational assignments are devoted to the national organization to economically optimise the management of common resources or equipment; in particular, (1) assistance for local owner assignment for national affairs or projects, e.g., steam generator tube controls and expertise, and steam generator replacement; (2) elaboration and updating of specific operational documents, e.g., methods of inspection and control of steam generator tubes, methods of pipe repair, accident emergency procedures, and periodic rules testing; and (3) full scope simulators are available in 3 national training centres.

Blayais ambition is based on five main ideas:

- to develop a direct social dialogue in the field to reinforce our cohesion;
- to develop and recognise individual professionalism by highlighting of the importance of speciality profession and the necessary complementary competences of all the staff;
- to produce at a lower cost to ensure the competitiveness of KWh by ensuring our role of owner assignment while guaranteeing the safety of the installation and the industrial safety of the workers;
- to progress in daily operation by close association with our contractors;
- to give a good image of the company by developing regional involvement.

FR.4. MANAGING AND WORKING AT BLAYAIS

FR.4.1. Management practices

Progress toward excellence at Blayais is based on five main goals:

- To develop a direct social dialogue at the plant to reinforce cohesion;
- To develop and recognise individual professionalism by highlighting the importance of speciality professions and the necessary complementary competencies of all the staff;
- To produce at the lowest cost KW h while guaranteeing the safety of the installation and the industrial safety of the employees;
- To progress in daily operation by close association with contractors;
- To create a good image of the company by developing regional involvement.

FR.4.1.1. Organizational structure

The organizational structure is clear and well understood by everyone. There must be coherence between staff, structure, and methods of management. Assignments and delegations have been formalized considering three factors: (1) the delegation of financial authority; (2)

the creation of working committees across divisions; and (3) the active incorporation of a sensitivity to human factors.

First, the delegation of financial authority concerns all decisions that influence work activity or equipment supplies. Authority is delegated from the site manager through the organizational structure to technicians, where each level has a different level of authority. This promotes motivation and provides better cost management.

Second, transverse committees create open-mindedness and give consistency to actions in the different divisions by defining main annual directions. About 15 committees were created six years ago as part of the top management site committee. Each committee is chaired by a member of the top management site committee and gathers members and experts from each division. Regular meetings are organised. Among the topics considered are safety, training, engineering, industrial safety, industrial policy, ALARA, operation, maintenance, liquid and solid releases, and communications.

Third, a human factors expert was appointed in 1994 as a member of the top management site committee to improve human performance. In the past, human intervention was considered a source of incident. As a result, work practices and the use of procedures came with prescriptive instructions. But industry experience has shown that organization, behaviour, expectations, and motivation are important. These factors are now considered in analysing significant events and by each operating team. A network of human factor representatives among production and maintenance employees participates in event analysis. Also, each operation shift develops an action plan of their own to improve performance of their team with the support of a human factors expert. Moreover, human factor items are progressively introduced in operation training sessions, for example, field staff situational training highlighting operational communication and specific event analyses training sessions based on case studies with numerous malfunctions linked to human interventions.

FR. 4.1.2. Strategies and goals

To maintain a high level performance, EDF's national goals are articulated in the utility management project. Linked to this, Blayais has a Triennial strategic plan. This is a reference document to direct the efforts of the plant's staff. About 60 managers drafted the Triennial strategic plan. This wide involvement gives consistency to the planned actions. Furthermore, an effort of information and communication was made through numerous meetings with first-line managers based on presentation of past results and discussions on objectives and future actions. This allows them to integrate tasks, procedures, and schedules and to co-ordinate with other groups.

In compliance with the Triennial strategic plan, every year a management contract is implemented in each division with a set of performance indicators and a specific action plan. Every quarter, periodic controls and analyses are done by the top management of each division and possible adjustments are made. At the end of the year, a critical analysis is made between what was expected and what really happened. Differences are stressed, some corrective actions are taken, and some actions are postponed for the next year.

In addition, every year results of divisions are compared to similar plants nationally and internationally. These benchmarking activities increase involvement and motivate the staff to reach the best results in the world for similar units. These activities also help create team spirit and a sense of ownership.

The utility management project consists of six basic initiatives for future evolution of each EDF site to enhanced safety and plant availability. These initiatives are (1) nuclear safety and operations, (2) nuclear safety and maintenance, (3) corporate services and site engineering, (4) cost control, (5) management information system, and (6) internal communication and public information.

(1) Nuclear safety and operations. The operation department and its shifts have been designated responsible for total operations and assumes responsibility for all the systems of the unit in normal operation and in outages. This responsibility imposes strong requirements in terms of operating the installation in normal and abnormal situations. It is therefore necessary to improve the professionalism and safety culture of the operations staff through adapted training programmes. The operations department must be open to external specialities and have a close working relationship with other departments, including a strong involvement in the outage and an active partnership with the maintenance department and the safety quality department (which carries out verification in the safety area and fulfils the role of support, assistance, and advice).

(2) Nuclear safety and maintenance. The objective is to optimise maintenance, considering safety, cost, unavailability, and industrial safety. This implies the development of a risk analysis culture and the reinforcement of preventive maintenance activities based on reliability centred maintenance. This requires the careful analysis and availability of an efficient engineering support department and the evaluation and incorporation of feedback after maintenance work. This also leads to a strong partnership policy with contractors to guarantee the quality of contracted maintenance activities. This policy must to take into account the social aspects of contracting, including the development of local industry and training contractors regarding safety, industrial safety, dosimetry, cost, and control objectives. To aid this effort, multi-year contracts have been developed.

(3) Corporate services and site engineering. The aim is to better anticipate major generic problems. The co-ordination of engineering support is enhanced through expressing management expectations, by clearly defining engineering's role, and by validating issues given to them.

(4) Cost control. The objective is economic efficiency by considering nuclear safety, cost, and job security. To achieve this, the staff must be more responsible at every level. A management control executive is designated for each division and provides support for heads of each section. Also, the establishment of an industrial policy regarding relationships with contractors is required to control expenditures.

(5) Management information system. The main objective of this system is to give access to all relevant information to all users. The objective is enhanced when all users master the system and when the system serves the users.

(6) Internal communication and public information. Internal communication is an integral part of management and should help each employee play an active role in the conduct of new developments. The efficacy of external communication relies on maintaining close and regular relationships with local elected representatives and local government, the media, and the public with visits of the plant.

FR.4.1.3. Management involvement and communication

Managers take an active role in task completion. Two aspects of involvement in task completion should be highlighted: line management industrial safety visit (VHS) and self-assessments. The VHS began three years ago to improve performance, cleanliness, and industrial safety. They began in the unit 1&2 production division. Last year they were implemented in the maintenance division and will be implemented in 1997 in the unit 3&4 production division.

The VHS involves a binomial line manager pair (n, n+1), who after preparation and review of previous VHSs, observe job performance to detect dangerous actions and situations and to identify good practices. Next, there is a discussion about corrective and preventive measures. This is followed by a one page report on the major observations, methods of measuring results, and an assignment of tasks. The primary results of this program have been changes in behaviour, better communication, and establishing a climate favourable to controlling risks and decreasing accidents and medical treatment. Each manager of a unit must make ten VHS per year. About 200 VHS were performed in 1995 and 1996 in production division units 1&2. A VHS committee has been created for co-ordination to decide specific actions, such as the creation of the "VHS challenge."

Self-assessment is closely linked to the management contract elaboration. The self-assessment is based on two aspects:

- **A thematic approach**. There are nine themes for maintenance and eight themes for operation. The head of a section manages the implementation. Four topics are analysed per year. Synthesis and action plans are created.
- **An internal review of procedural documents**. Each manager must identify differences between these documents and practices. Each manager must review differences in two organizational documents each year.

As a result of this process, some corrections have been implemented immediately and some actions have been implemented in management contract. These self-assessments have given managers an opportunity to participate in task completion and to improve communication with employees.

FR.4.1.4. Relationships with contractors

Maintenance activities at Blayais involve an estimated 1000 contracted staff, mainly during refuelling outages. Regarding its relationship with contractors, EDF has dedicated a significant effort over the last few years in (1) improving communication with companies to enable then to better schedule their workload; (2) reducing exposure; (3) establishing identical medical follow up for all EDF and non-EDF staff; and (4) improving working and living conditions. These commitments were formalized in a "progress charter" signed in January 1997 at a national level with the representative organizations of subcontracting companies. The objective of this partnership is to guarantee quality, safety, and competitiveness of French NPPs. To implement this policy, an industrial policy expert was appointed three years ago with this unique assignment.

To improve company visibility and job stability, three year contracts have been signed and the volume of contractors' hours will nearly triple within two years (85,000 h up to 213,000 h). In addition, actions launched over the last few years have significantly reduced individual and collective exposure. In terms of personnel exposure, EDF has decided to not utilise any EDF or non-EDF worker with a dose exceeding 20 mSv/y by the year 2000. Finally, the Progress Charter also focuses attention on enhanced professionalism and safety culture. Since 1993 at national level, 20000 non-EDF workers have enrolled in a training session entitled "contractors quality and safety training," which targets improved knowledge, risk analysis, and prevention. A follow up session, including skill maintenance, takes place three years later. This training is compulsory for all staff, including temporary workers.

FR.4.2. Personnel

FR.4.2.1. Personnel characteristics

The 1100 Blayais employees, most of whom are technicians, are divided into four divisions: two production divisions (one for units 1&2 and one for units 3&4), a technical division, and a management division. (See Attachment FR.A3.)

The role of each production division is to monitor electricity production 24 hours a day in the control rooms on the basis of real time information on the various systems. Both of these divisions are organised in the same way and have the same number of employees (about 280 people) mostly technical staff. Operating staff works in three 8 hour shifts. In order not to interrupt production outside normal working hours, staff on stand-by duty carry out maintenance and verifications.

The 300 employees in the technical division are in charge of maintenance and managing unit outages. They are also responsible for chemical and radiation monitoring of the environment. Many technicians must work on a continuous shift schedule when the units are shut down, then go back to more normal working hours when the units are back in regular operation. Almost all departments in the Technical Division have staff available to work round the clock when necessary.

The management division, including the management team and its management board, is responsible for managing the staff and assets of Blayais. About 150 people work in this division: managers, accountants, buyers, training personnel, and security staff (who work around the clock), as well as doctors and medical personnel (who are also available at all times). The facility has 35 managers with specific responsibilities in fields such as communication, human resources, industrial policy, management control, safety-quality, engineering, and internal auditing.

Although life at Blayais is generally calm during operation, it intensifies when the units are shut down. Work done at this time amounts to an average of one million man-hours per year. This calls for all types of technical skills, some of which are either extremely specific or temporary, and need to be sub-contracted. Each year, 70% of maintenance work is sub-contracted to regional and national firms.

Recent developments in staff composition have been implemented to comply with five objectives:

(1) **To put decision making closer to the field for operation**. In addition to shift supervisors, shift managers, responsible for safety, operation, and human resources have been designated (one per shift, plus two additional).

(2) **To reinforce defence in depth.** For the safety quality department, safety engineers with tasks in safety quality review, assistance, and advice were taken off shift (although operational tasks in emergency situations remain).

(3) **To develop local owner assignment in maintenance.** For maintenance staff, reduction of workman numbers and increase in planners, preparers, and checkers to reinforce preparation and control of work of contractors (at the same time involvement of contractors has increased).

(4) **To increase local analysis potential.** For technical support staff, implementation of local engineering in mechanical, I&C, electricity, and operation, as well as a specific co-ordinator on the site.

(5) **To reinforce training.** For training centre staff, two additional instructors were added to develop training for operations personnel.

The Blayais employees and management have shown their ability to perform consistently with quality, particularly if there is a need, for example, during outages and unplanned work following an incident. This professionalism is characteristic of work for the majority of employees on site and is rooted in specialisation of the involved professions and the involvement of the entire staff in safety and availability objectives.

The high level of personnel qualification contributes to a mastery of safety, quality, and cost. These qualifications are documented in Attachment FR.A4. Three features are highlighted here: staff ages, staff function, and classification of personnel according to their academic level.

First, the average age increased from 36 in 1991 to 38 in 1996. This ageing of the workforce implies a need to prepare for recruitment in the near future. One positive aspect of this ageing is the increasing experience of the staff, but a negative aspect could be the risk of routinization.

Second, from 1991 to 1996, there was significant reduction of 80 staff in the field with an increase of 80 staff in middle management and 49 staff in management. This has come about from the need for more engineering, preparation, analysis, and checking and less need to carry out activities.

Third, there has been a significant increase in levels of education:

- 13% of the workforce in 1991 had a BAC (a national examination at age 18) and 25% had it in 1996;
- 8% in 1991 with BAC + two years and 12% in 1996;
- 3.7% in 1991 with BAC + four years (graduate level) and 4.9% in 1996.

This increase in education has been distributed as

- 30% with graduate level for management;
- 18% with BAC + two years for middle management;
- 25% with BAC for other employees.

Although education attainment has been increasing, company objectives for the year 2000 are 40% with graduate level for management, 35% with BAC+2 years for middle management, and 25% with BAC for other employees.

FR.4.2.2. Personnel development and training

Although it is difficult to directly relate training programmes with improvements in plant performance, there is a link. Considering the number of training hours per employee, per year, between 1990 and 1996, we can observe a stabilisation for all employees at about 120 hours annually and a significant increase for operations staff to about 160 hours. For operation staff, the training objectives are 140 hours per year for people on site and 200 hours per year for people in the control room.

However not only is the volume of training important, but also its quality. Therefore, at Blayais in 1992, the operation training centre was created to provide both volume and quality of training to improve knowledge on physical processes and to enhance analytic capabilities in normal and accident operation. (Full scope simulators are installed at national training centres and are not available on site). Two instructors are dedicated to this local training centre and three function simulators are at the disposal of the operation staff. In addition, static mock-ups are available to show equipment in space and dynamic mock-ups are used to show thermodynamic, heat exchange, and regulation processes. A post-accident simulator is now implemented to simulate in real time, accident phases on computer screens showing trends of physical and thermodynamic parameters and pictures from the primary circuit with different types of flow.

Associated with the importance of establishing an operator training centre is the importance of the interface between shift teams and the operation training centre. To address this issue, a site training committee with the head of the production department, shift managers, operators, field workers, and instructors was created to identify and develop training needs and use operating experience feedback in training. Therefore,

- The operation training centre has developed its syllabus in co-operation with the operations departments. Instructors are allocated to facilitate the development of each training need with a training package. The process involves the customers at each stage: objectives, training specification, training content, training package, and the evaluation of a pilot training session.

- Operation experience feedback is systematically incorporated into training. Additionally, trainers have a weekly meeting where new external and in-house events are presented. They discuss the interest for training and classify this information into areas such as primary or secondary. This information is available for all trainers and is reviewed for incorporation when training is revised or created.

- Trainee feedback is taken into account when reviewing training. Training centre trainers are given all of the site training teaching files to review. They must review all of the "synthesis" (trainee feedback) sheets and summarize the comments for presentation to the Training Manager at the annual review. An action plan is developed to improve the training packages.

- The human factors training was developed and implemented in co-operation with the shift managers and technical supervisors. Half-day sessions are run so employees can understand the problems and support the implementation of the solutions.
- Senior managers are involved in the development and evaluation of significant non-technical training initiatives.

Moreover, in the non-technical training area, two years ago, management courses for first line managers (head of section and foreman) were introduced to enhance their knowledge of the management process. The objectives of this training are (1) to analyse different types of management; (2) to enhance knowledge about the management environment and objectives of the company; (3) to understand their role in the company; and (4) to help them assess consistency between national and local orientations.

Also, managerial and leadership development is a priority at Blayais. Much management time is dedicated to the planning and oversight of personnel development. Managers take an active role in training. In training, senior managers are involved in the development and evaluation of local training. They systematically attend end-of-course evaluations. They discuss the general organization and possible improvements in training. These evaluations are considered when reviewing training. This focus has resulted in the following initiatives: (1) training is under development for technicians before their promotion to superior positions and for supervisors to assist them in their transfer to section head positions and (2) there are many opportunities for individuals to develop themselves for job changes.

Employees can express their wishes at annual evaluations with their supervisors. The annual individual evaluations apply to everyone. They are based on a direct and formal dialogue between the manager and the employees. They enable evaluation of each individual situation and encourage staff to be more involved in their professional career. Further, everyone can consult an on-site professional adviser who can give them advice on different career opportunities. This can lead to the elaboration of an individual professional plan that co-ordinates individual wishes and company needs. The plan is a contract between the employee and the manager that designates the implementation of targets, new on the job training needs, and time objectives. As a result, individuals are provided tools for the preparation of future assignments and personnel are available for future leadership positions.

FR.4.3. Working practices

FR.4.3.1. Plant status control

To ensure that systems and equipment are controlled in a manner that supports safe and reliable operation, the shift supervisor provides a safety assessment for a comprehensive review of operational parameters important to safety. Each shift supervisor performs a safety assessment of the unit status by reviewing the safety system status provided by the plant computer. The shift supervisor evaluates the abnormal condition and documents the condition on the safety assessment sheet. Additionally, the shift supervisor performs a detailed walk-through of the control panel reviewing indicators and illuminated annunciators. Corrective actions are initiated as necessary by the shift supervisor. The shift supervisor safety assessment verifies the condition of the unit and provides important information to the shift teams about the current status of the plant.

Procedures for periodic tests important to safety equipment describe all activities from initial briefing through test performance, including actions required when a test does not meet the acceptance criteria. In addition, the test procedure includes all activities inside and outside the main control room. Preparation before testing includes briefing the reactor operators and the field technicians. Each test procedure contains communication hold points to allow the reactor operators and technicians to exchange information. Moreover, a letter "D" on the annunciator window uniquely identifies annunciators that are important to the diagnosis of station events. The unique identifier allows the reactor operator to quickly identify the most important annunciators. The reactor operators then respond immediately by using a specific diagnostic flowchart.

FR.4.3.2. Operations

To ensure effective implementation and control of operations activities, a specific management system has been developed and applied to sensitive operations transients. An operation transient is "sensitive" when the following conditions are met:

- Fulfilment of one safety function (reactivity, cooling, containment) is challenged during the operation transient.
- There are operating condition limits to be fulfilled.
- The defence in depth barriers are human (not physical or automatic).

The sensitive operation transient management system consists of sensitive operation transient identification, pre-analysis of risks to nuclear safety, and the identification of preventive measures to be taken to ensure the fulfilling of nuclear safety functions. So far, ten sensitive operations transients have been identified. As soon as an operation transient is considered sensitive, a complete pre-analysis of risks to nuclear safety is conducted by the engineering support team, shift managers, and safety engineers. Based on this pre-analysis, preventive measures to be taken, and specific parameters to be monitored are identified to prevent any potential failure of defence in depth barriers. The pre-analysis results of sensitive operations transients are individually formalized in an "ASTUS" sheet, which provides a synthetic picture of sensitive operations transients to operation teams regarding nuclear safety. In addition to the ASTUS sheet, a specific "briefing" sheet (which is used by the shift manager during the operation team briefing prior to starting a sensitive operation transient) is prepared to help the shift manager identify key points. The effectiveness of this management system has been demonstrated and observed during recent annual plant outages.

FR.4.3.3. Maintenance

FR.4.3.3.1. Policy

To guarantee appropriate availability of equipment, conditional maintenance is systematically carried out. It consists of monitoring equipment characteristics when operating. Two kinds of equipment are monitored: rotating equipment and static equipment. Measurements are based on vibration measures for rotating equipment and acoustic measures for static equipment. For each production unit, the conditional maintenance team is composed of two technicians for rotating equipment and one technician for static equipment under the responsibility of a foreman.

In addition, a preparer is in charge of conditional maintenance analysis linked to elaboration of synthesis, follow up, and development. Systematic syntheses are also carried out two months before an outage with precise indications of equipment concerned and maintenance actions to be implemented. These corrective actions may have an impact on the outage programme: some maintenance actions may be removed and some others may be added. This process has proven economic for safety equipment maintenance in terms of optimisation of maintenance activity and will be extended to monitor areas of the plant not considered essential to support nuclear safety. Furthermore, new applications of conditional maintenance are studied, such as the surveillance of electrical servomotors and leak-tightness test of valves.

FR.4.3.3.2. Planning and scheduling

A good availability depends on success in an outage and readiness for unplanned outages. The planned outage is a complex affair that requires various competencies, important resources, and a specific organization: the project management. Two main objectives are assigned to this project: (1) internal, involving the mobilisation of the participants and (2) external, involving the integration of Blayais in partnership with other companies. The primary participants in an outage organization are:

- The outage engineer who is responsible for the outage in terms of preparation, co-ordination, and experience feedback.
- The operational team who implements the programme and consists of several work co-ordinators per speciality responsible for all the aspects (regulations, technical requirements, cost control, dosimetry, safety requirements, deadline, quality, industrial safety).
- An assistance team who provides support for each of these objectives.

Among the concrete applications are (1) for safety, the list of works, tests and modifications on safety related equipment that is prepared six months before the outage; (2) for economics, the outage budget, which is developed six months before the outage; and (3) for social aspects, the contractors who are chosen four months before the outage, and starting meetings that are organised two months before the outage (discussion of dosimetry and industrial safety are included in these meetings). In addition, the outage is presented by the management to trade unions and employees one month before the outage. The strong points of this organization are

- direct involvement of the management leading to rapid decision making in all areas
- the quality of the preparation with significant impact on cost, dosimetry, and duration
- a common outage schedule for all specialities.

FR.4.3.3.3. Readiness for unplanned shutdowns

To be ready for the unplanned outages requires that much of the shutdown planning has been done when an unplanned outage occurs. A shutdown work list is maintained and updated weekly showing jobs in three categories: (1) those that can be accomplished with the plant in hot standby; (2) those that must be done with the plant in cold shutdown; and (3) those that require a refuelling outage. These jobs are maintained on a computerized program of maintenance management that includes parts inventories, labour force scheduling, and other techniques to optimise manpower and inventory levels. Responsibilities are assigned in advance, wherever possible, for the three types of outage.

FR.4.3.3.4. Risk analysis in maintenance

A specific approach has been implemented to define measures taken into account to master risk linked to temporary modifications. To comply with this risk, practical measures are taken (1) to identify the temporary modification, for example, paint blind flanges, labels on electronic modules, coloured jumper wire; (2) to mark the temporary modification devices; and (3) to manage the temporary modification devices physically and administratively, i.e., the first line in the defence in depth. The information system enables an inventory of those devices with a permanent and exhaustive traceability of devices in force. To guarantee the return to a normal situation, a follow up is required based on the implementation of the functional requalification, the updating of the administrative tools, the controlling of the absence of temporary devices, and the final requalification.

FR.4.3.4. Technical support and other activities

To co-ordinate technical support at Blayais, there is a specific experience feedback commission with three main roles: to select events, to decide if analysis is relevant, and to assess each case. Two kinds of events are analysed (1) internal events that occur at Blayais and (2) external events at other national or international sites. The commission is chaired by the specific engineering co-ordinator and gathers representatives of each speciality (production, maintenance, industrial safety, training, and safety). Each representative must collate events linked to his speciality, such as malfunctions or good practices and manage the analysis and information in his section. There is a weekly meeting and a follow up of decided actions with a deadline and a pilot.

TABLE 3. ENERGY AVAILABILITY FACTOR

ANNEES	REP 900MW	BLAYAIS	BLAYAIS 1	BLAYAIS 2	BLAYAIS 3	BLAYAIS 4
86	83.2	85.4	87.8	83.2	88.3	82.5
87	78.6	85.6	78.1	84.8	93..8	85.6
88	79.0	81.8	82.0	91.1	82.7	71.5
89	78.6	83.3	84.2	77.0	82.7	89.4
90	76.5	78.1	77.2	87.4	64.3	83.4
91	72.6	80.1	83.8	78.3	84.6	73.5
92	72.0	77.9	57.5	86.9	83.0	84.1
93	81.5	81.9	83.7	71.0	87.7	85.3
94	82.0	78.9	86.6	88.7	57.8	82.6
95	82.0	84.0	87.1	87.9	85.9	75.2
96	83.1	87.8	88.5	87.4	87.1	88.2

TABLE 4 — PLANNED ENERGY UNAVAILABILITY FACTOR

ANNEES	REP 900MW	BLAYAIS	BLAYAIS 1	BLAYAIS 2	BLAYAIS 3	BLAYAIS 4
86	12.0	12.1	10.5	14.3	10.6	13.0
87	13.0	11.0	16.5	10.9	5.8	10.6
88	11.0	12.3	12.6	4.4	12.4	19.7
89	13.3	11.5	12.5	20.5	12.4	0.5
90	17.2	15.9	18.5	10.5	22.0	12.7
91	18.2	15.0	12.7	18.7	12.5	16.3
92	17.2	16.9	27.4	12.5	12.5	15.5
93	15.1	16.3	11.3	27.8	12.2	13.6
94	13.6	16.0	12.2	11.1	26.9	13.9
95	13.1	15.3	12.1	11.1	13.9	23.9
96	12.3	10.8	10.2	12.2	10.6	10.3

TABLE 5. UNPLANNED ENERGY UNAVAILABILITY FACTOR

ANNEES	REP 900MW	BLAYAIS	BLAYAIS 1	BLAYAIS 2	BLAYAIS 3	BLAYAIS 4
86	3.8	1.7	1.0	0/7	0.7	4.5
87	5.0	1.3	2.1	2.0	0.4	0.7
88	4.7	2.6	3.0	4.5	1.6	1.5
89	3.2	1.6	3.3	0.6	1.0	1.3
90	2.7	1.2	0.8	2.0	1.5	0.6
91	3.1	0.8	0.9	1.3	0.7	0.3
92	2.8	2.1	8.1	0.1	0.0	0.3
93	2.0	0.7	0.8	0.9	0.1	0.8
94	2.1	1.2	1.2	0.2	0.1	3.5
95	2.2	0.4	0.0	0.5	0.1	0.9
96	2.8	1.4	1.3	0.4	2.3	1.6

TABLE 6 — EXTENSION OF PLANNED ENERGY UNAVAILABILITY FACTOR

ANNEES	REP 900MW	BLAYAIS	BLAYAIS 1	BLAYAIS 2	BLAYAIS 3	BLAYAIS 4
86	1.0	0.8	0.7	1.8	0.5	0.0
87	3.4	2.2	3.3	2.3	00	3.1
88	5.3	3.3	2.5	0.0	3.2	7.4
89	4.9	3.6	0.0	1.8	3.9	8.6
90	3.6	4.8	3.5	0.1	12.2	3.2
91	6.2	4.1	2.7	1.7	2.2	10.0
92	8.0	3.1	7.1	0.5	4.5	0.1
93	1.4	1.2	4.2	0.3	0.0	0.3
94	2.3	3.8	0.0	0.0	15.2	0.0
95	2.7	0.4	0.8	0.5	0.1	0.0
96	1.8	0.0	0.0	0.0	0.0	0.0

TABLE 7 — SIGNIFICANT EVENT (INES)

	90	91	92	93	94	95	96	Last 5 Years
SITE	9	5	3	7	3	6	2	4.2

Up to 92, French significant Event Scale.

TABLE 8 — UNPLANNED AUTOMATIC SCRAMS (nb/700h)

	89	90	91	92	93	94	95	96	Last 5 Years
Unit 1	0	1	1.87	2.75	1.90	0	0	5.36	2.00
Unit 2	2.05	3.73	3.05	1.84	3.32	2.72	2.69	1.83	2.48
Unit 3	0.95	4.79	1.85	0	0	1.37	0	0.90	0.45
Unit 4	4.70	0.94	0	0.93	3	0	5.54	2.67	2.43
SITE	1.93	2.62	1.69	1.38	2.05	1.02	2.06	2.69	1.84

TABLE 9 — INDUSTRIAL SAFETY ACCIDENT RATE (EDF STAFF)

	86	87	88	89	90	91	92	93	94	95	96	Last 5 Years
SITE		7.8	11.1	6.2	12.2	8.2	5.7	7.8	8.5	5.7	10.5	7.64

TABLE 10 — COLLECTIVE DOSIMETRY (EDF + CONTRACTOR STAFFS)

	86	87	88	89	90	91	92	93	94	95	96	Last 5 Years
SITE		1.95	2.28	2.43	3.08	3.39	3.31	2.63	2.83	2.37	1.82	2.59

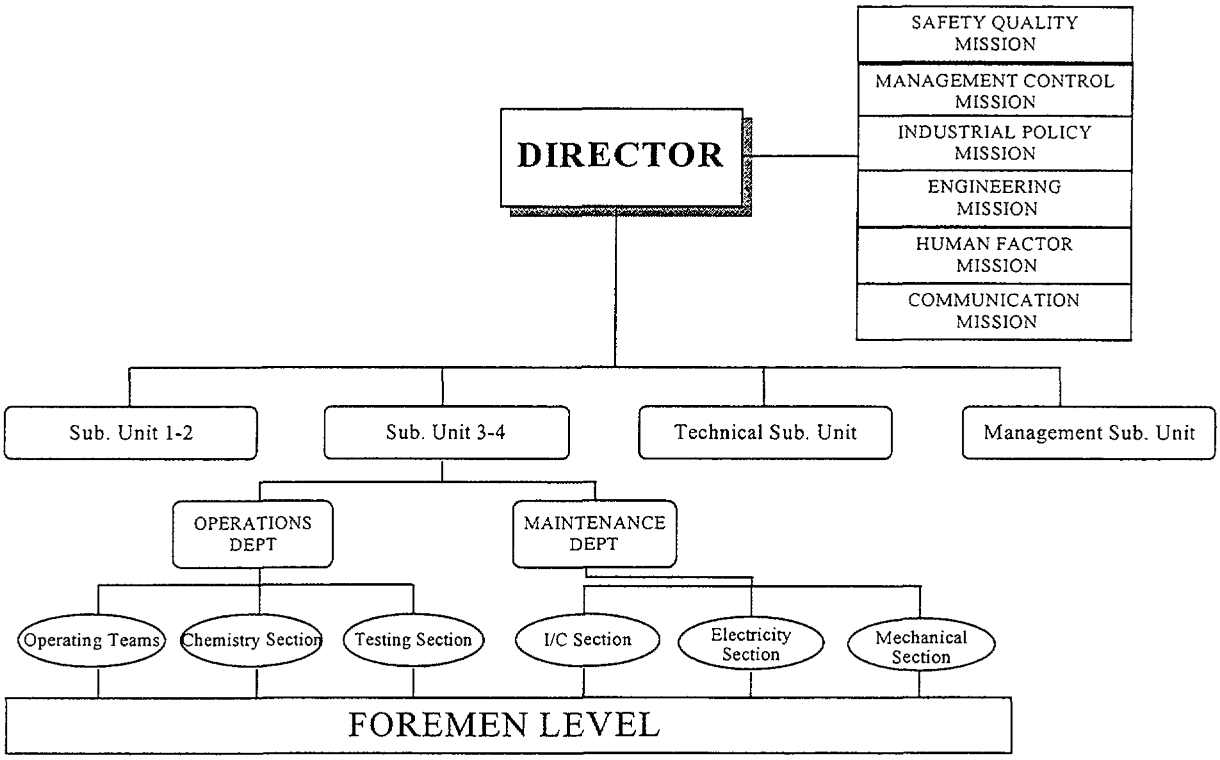


FIG. 1. Diagram of staff.

TABLE 11. PERSONNEL QUALIFICATION

	1991	1992	1993	1994	1995	1996	EVOLUTION
AVERAGE AGE	36	36	37	37	38	38	3
< BAC	75.2%	67.23%		65.65%		58.89%	-16.63%
National Examination at age of 18	12.81%	20.04%		20.16%		25.05%	12.24%
BAC + 2 years	8.00%	8.81%		9.94%		11.89%	3.89%
graduate level	3.67%	4.02%		4.25%		4.17%	0.50%
Staff in the field	266	235	229	225	203	193	-80
in middle management	655	685	675	687	697	722	90
in management	141	148	158	174	183	187	49
Total	1062	1068	1062	1086	1083	1102	49

Annex D: PAKS CASE STUDY

HU.1. PLANT DESCRIPTION

The Paks Nuclear Power Plant (NPP) is the only nuclear power station in Hungary. It is located 116 km south of Budapest, 5 km south of Paks on the right bank of the Danube river in the centre of the country.

The Paks NPP has four WWER-440/213 type reactor units. Each unit has a 1375 MW thermal capacity and two turbines, each with a power of 230 MW(e) (after reconstruction, the original design was 220 MW(e). The reactor coolant system (RCS) consists of six loops (with its primary piping, horizontal steam generators (SG), main circulating pumps (MCP), and main gate valves). The pressurizer is connected to a hot leg of either loop N°.1 (odd units) or loop N°.6 (even units). Condensers are cooled by the fresh Danube water through the inlet and outlet channels. Turbines operate with saturated steam of 256°C and 4.46 MPa with a speed of 3000 rpm. There are five low pressure preheaters, a deaerator feedwater tank, and three high pressure preheaters for each turbine.

The reactor core consists of 312 fuel assemblies of a hexagonal shape containing ^{238}U enriched by about 2.5% of ^{235}U. The reactor power and fast changes in reactivity are controlled by 37 control rods of a stainless borated steel connected with a fuel part on its bottom. It is inserted into the core whenever the control rod is withdrawn from the core and vice versa. Slow and long term reactivity changes are compensated by injecting borated water (boric acid) into the RCS. At nominal power, the RCS pressure is 12.4 Mpa with an average temperature of 282°C.

During normal operation, the reactor power and SG pressure is maintained and controlled by the automated power controller (ARM) acting through control rod drive mechanism. In case of an excessive or fast power increase, with a substantial change in plant parameters or component operation, the reactor is protected by a power limitation controller and reactor protection system divided into four levels ranging from stopping the control rod withdrawal to a reactor scram. The units are also equipped with engineered safeguard features (ESF) designed to mitigate consequences of a transient involving a fast RCS cool down or a loss of reactor coolant for various reasons. These features are performed by safety systems divided into four categories:

(1) Passive emergency core cooling system consists of four hydroaccumulators that flood the core in case of a drop in RCS pressure.
(2) Active emergency core cooling system represented by three trains of a high pressure injection system (thanks and pumps) and three trains of a low pressure injection system (water storage tanks and pumps), injecting borated water into circulating loops and the reactor upon actuating the ESF.
(3) Active confinement pressure suppression system (ACPSS) represented by three trains of confinement spray pumps and heat exchangers cooling water discharged from a confinement sump. (The units not equipped with a standard reactor containment, but the reactor, RCS, ECCS, and PCPSS are located in a special sealed, reinforced concrete compartment called a "confinement.")
(4) Passive confinement pressure suppression system (PCPSS) consisting of twelve shallow water pools (bubble-condensers) above each other, where the discharged reactor coolant expanded into a steam condensate. In case of excessive pressure, the borated water in the pools overflows and additionally sprays the confinement.

HU.2. HISTORICAL PERFORMANCE

Construction of Paks started in 1966 with the signing of a preliminary agreement between Hungary and the Soviet Union. It was followed by the 1968 decision to construct two units the WWER-440/230 reactors (older type). The site preparation work started in the spring of 1969 but work was stopped and did not resume until 1974, when a decision was made to change the original plant design to four WWER-440/213 reactors (advanced type). The following table provides an overview of the Paks NPP construction and commissioning.

TABLE 1. PAKS NUCLEAR POWER PLANT — MAIN DATES

Unit	Start of Construction	First Criticality	Grid Connection	Commercial Operation
1	08.1974	14.12.1982	28.12.1982	10.08.1983
2	08.1974	26.08.1984	06.09.1984	14.11.1984
3	10.1979	15.09.1986	28.09.1986	01.12.1986
4	10.1979	09.08.1987	16.08.1987	01.11.1987

HU.2.1. Plant operating performance

During its operating history, the plant has been continuously improving its performance. The following chart of electricity generation during the entire plant operating history illustrates its stable and reliable operation.

Paks has provided more than 40% of Hungary's electricity for more than 8 years following the start-up of the 4^{th} unit. The production rate has been stable.

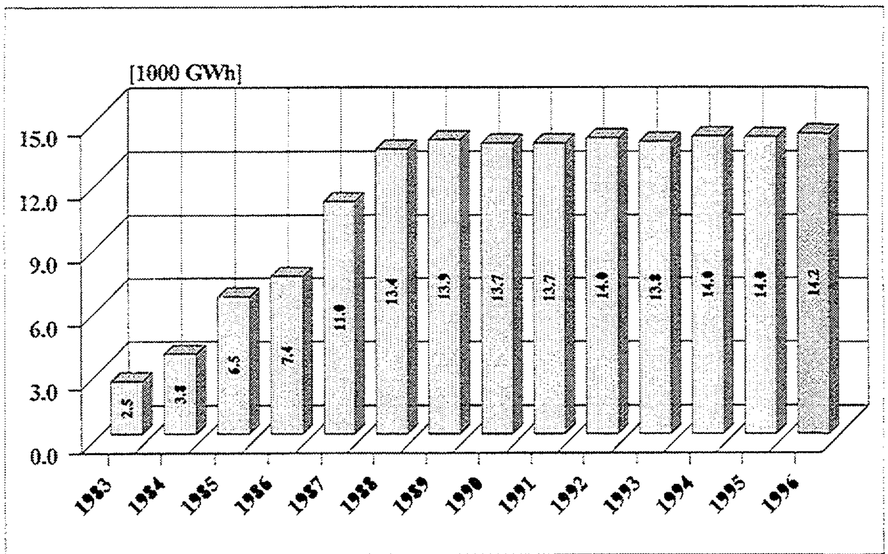


FIG. 1. Total electricity production of the Paks NPP.

The largest contributors to the production losses are refuelling outages.

Some PRIS and WANO indicators have been selected to illustrate the trends in performance of the plant based on data of individual units.

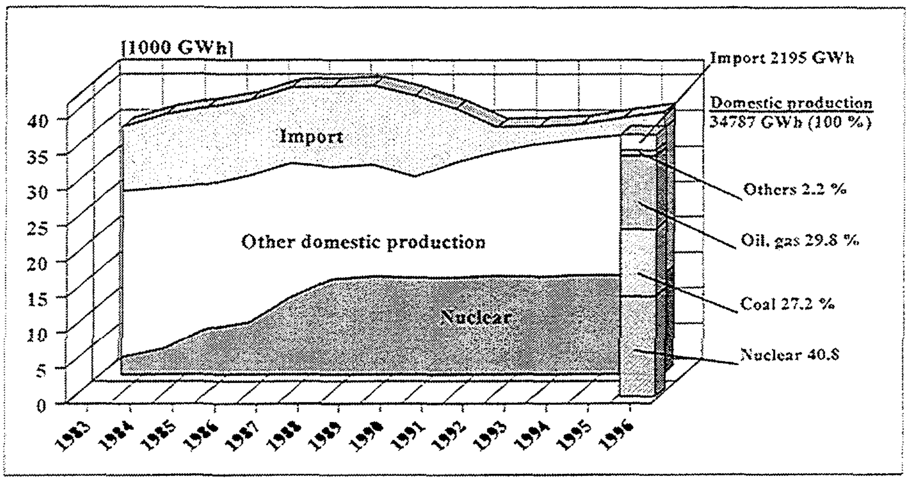


FIG. 2. Hungarian electricity.

The following three charts present the energy availability factors, unit capability factors, and unplanned capability loss factors over the studied period.

Annual values of the plant EAF are influenced by a four-year cycle of maintenance and refuelling outages. This cycle means that every fourth year an extended refuelling outage takes place at each particular unit with a total removal of fuel and reactor internals, as well as a series of inspections of the reactor pressure vessel and the entire reactor coolant system is carried out. These extended outages are carried out in 55–65 days, while the short outages are about 26–36 days. As it can be seen in Figure 3, the EAF values for the Paks units are relatively high, and the average values show a slight increase during the 1990s. The only way to increase the EAF in a long term is the decrease of the outage times by organizational and other measures.

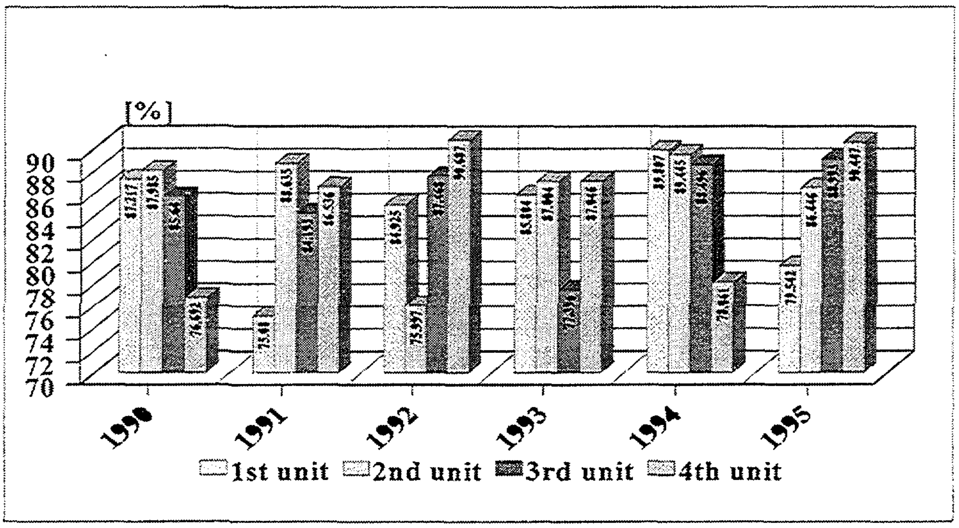


FIG. 3. Energy availability factor.

The unit capability factor (UCF), a WANO indicator, has been recorded since 1989. These values can be considered also on a four-year cycle basis.

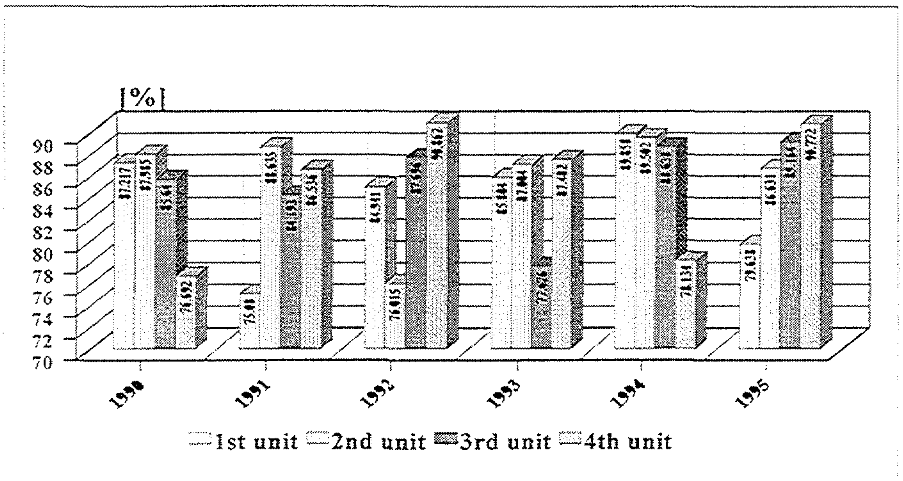


FIG. 4. Unit capability factor.

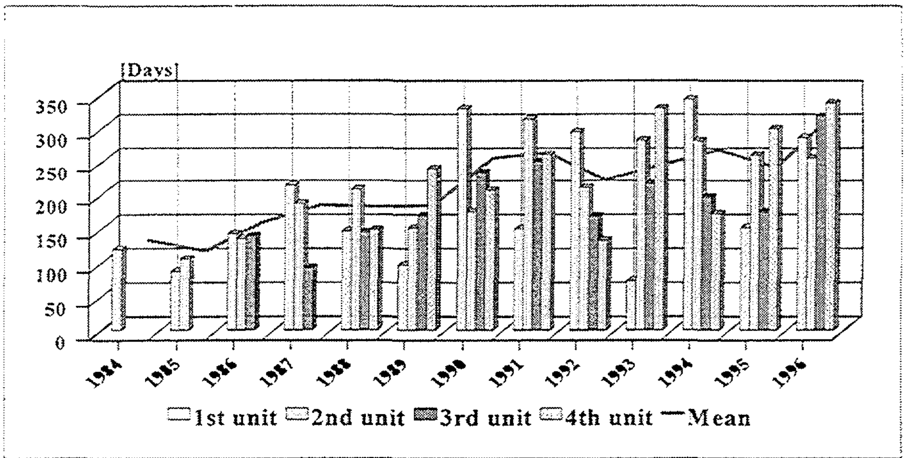


FIG. 5. Longest continuous operation of the units.

The unplanned capability loss factor (UCLF) is presented in the same way as the previous indicators. In addition to the UCLF, the trend in the longest continuous operation shows a high level of operational quality, culture, and operational safety. However a real trend in UCLF values cannot be determined in a 4 year period.

Given these statistics, it is difficult to predict the future trends for these values. To maintain the outstanding values for a longer period requires strategic planning, because the units have nearly reached half their designed life. Some strategic steps have been taken or are underway to meet the goals of future plans, including condenser replacement, preparation for the 4-year fuel cycle, ageing management, etc.

There are several guiding instructions that an operator should follow. The first is to produce electricity at the highest possible level. This means refuelling outages should be as short as possible. The ideal fuel cycle does not include any unplanned activities and the planned refuelling is as short as technically possible. Such an ideal cycle can serve as a general goal for operators. To reach this goal is not easy. But the trend to reduce the refuelling period, concentrating on the maintenance planning and human and material resource management can be seen in Figures 5 and 7.

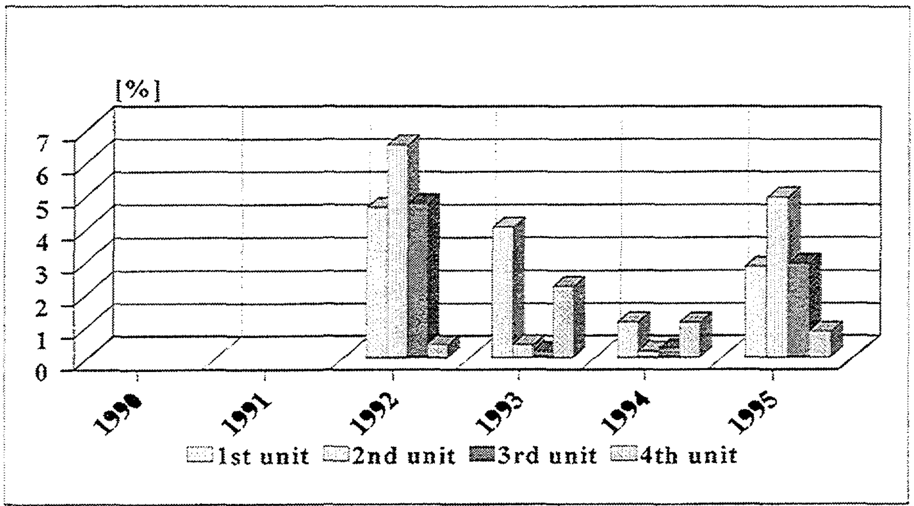


FIG. 6. Unplanned capability loss factor.

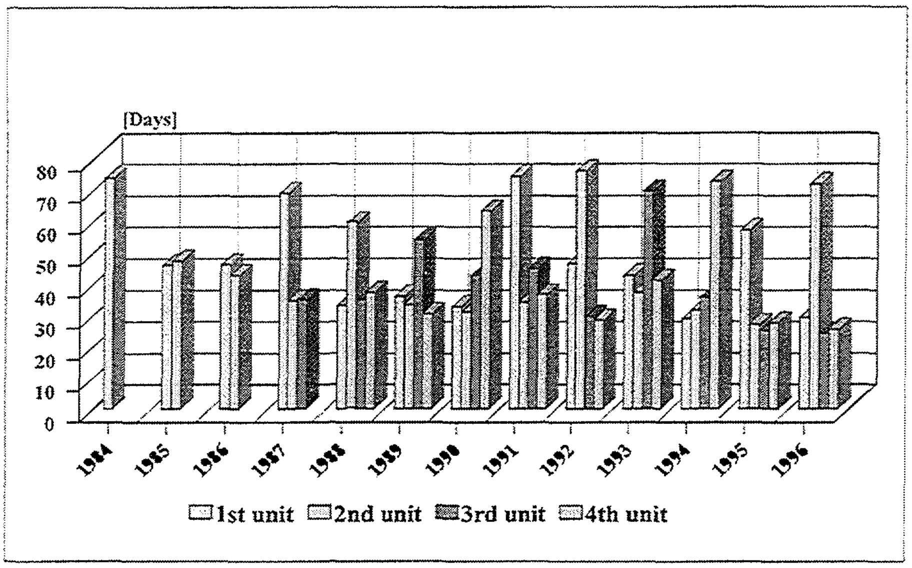


FIG. 7. Duration of the refuelling outages.

HU.2.2. Safety aspects of plant operation

Five indicators have been selected to illustrate the plant operation not only from the availability standpoint but also from the operational safety view. Most representative are the number of reactor scrams and the number of events rated higher than 0 according to the INES. The history of these indicators is shown on the following two figures.

The trend in the number of reactor scrams in the first and third years of operation was marked by the commissioning of the individual units. After this transient period, the situation stabilised. In the 1990s the annual average was 0.9 scrams per unit. (These scram averages include both manual and automatic scrams.)

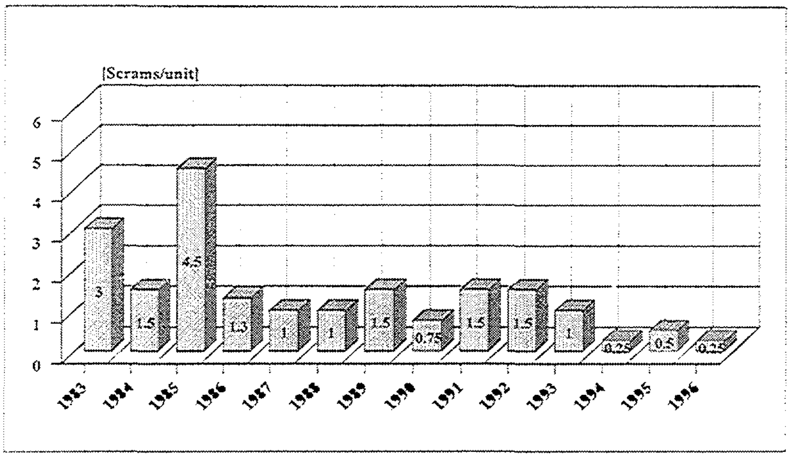


FIG. 8. Average reactor scrams.

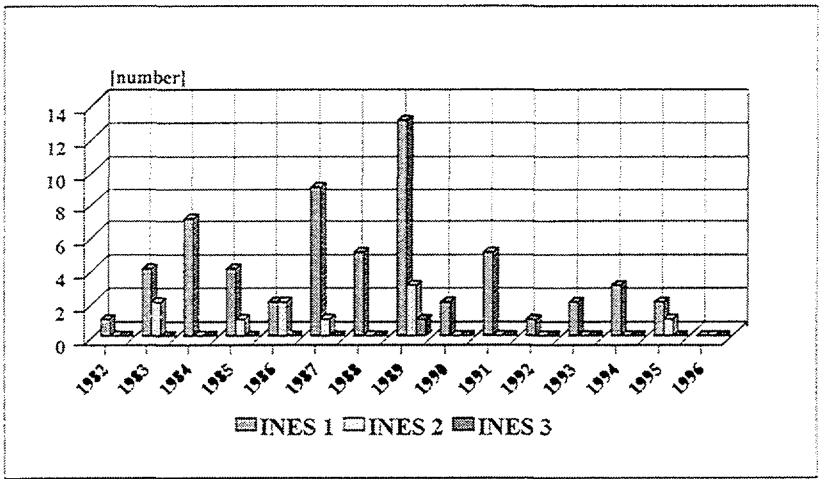


FIG. 9. Events higher than 0 according to the INES scale.

Paks has followed the INES indicator since the Chernobyl accident. The values before the accident were calculated to the present to show the reduction of these events and to assure the public of the safety of the WWER units. There has been a slight decrease in this indicator. The number of INES 1 events is low with an average of 0.625 events per unit per year. During the 1990s, only one INES 2 event occurred at the plant. These low numbers of reactor scrams and significant incidents also contribute to high plant availability, reliability, and safe operation.

The collective dose rates during refuelling show the trend of the particular units going through extended reactor maintenance. Collective dose rates for units having short maintenance are relatively low. The radiological environment is convenient for the work phases on these units. On the other hand, as units age, the radiological situation for extended refuellings is becoming more serious. The decontamination of particular equipment has become more important and time consuming activity. The more important is to have a self-assessment and general goals to follow during work planning.

Figure 11 presents the industrial accident rate per 1000 employees. There was a continuous decrease after the first years of commissioning.

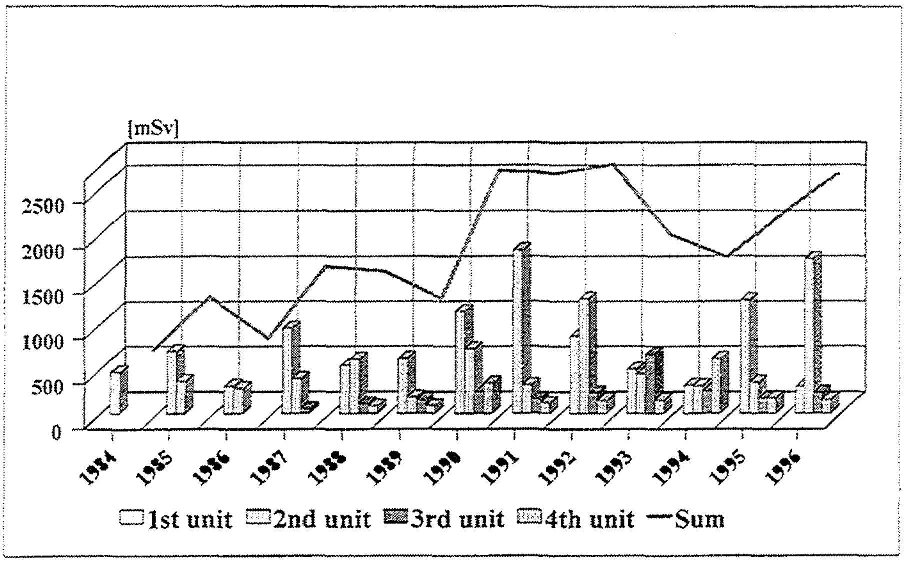


FIG. 10. Operative collective dose of refuellings.

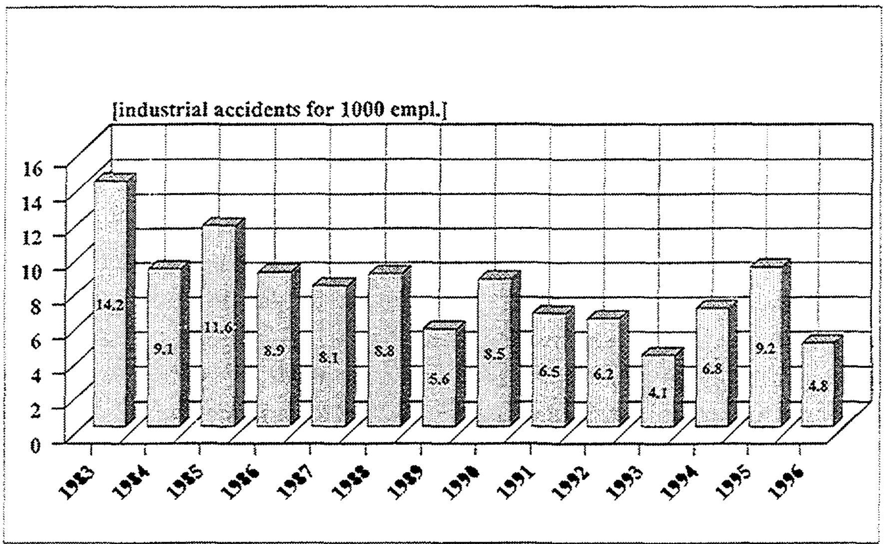


FIG. 11. Industrial Accident Rate Related to 1000 Employees.

Figure 12 presents a formalized goal of the Paks management. Since 1993, the limit for annual maximum personal dose rate of 20 mSv/year was maintained each year.

HU.3. OVERVIEW OF THE PAKS CASE STUDY

There are several aspects that contribute to the high standards of the Paks plant availability. Probably the most important aspect has been the team of highly qualified, devoted, and responsible professionals. The management has tried to keep a high level of performance and identify problems that might adversely affect performance. The plant actively participates in many international programs to improve performance through independent evaluations and reviews.

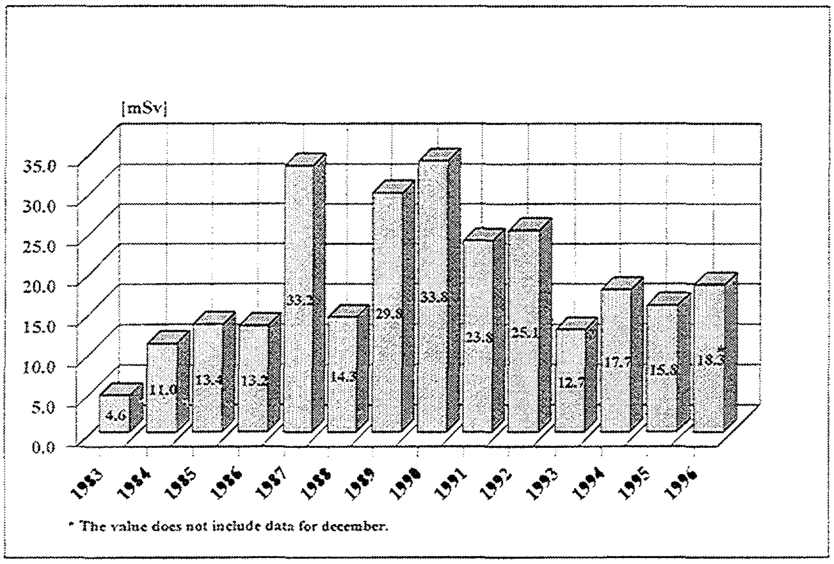


FIG. 12. Annual maximum personal dose rates.

To increase the level of plant technology, many upgrading projects have been implemented to eliminate existing deficiencies. The management has taken actions to improve plant operating and administrative procedures. A QA system has been widely implemented. The level of plant qualification has been kept high by the educational and training system, including regular examinations. The plant management has also taken actions to steadily improve internal communication and to create a good working environment.

Paks management operates the plant with the requirements of the owners and knowing the technical limitations. A general goal is to maintain the competitiveness of the plant operating safely with a high availability. This general goal is transferred into particular goals for the following areas: production, safety, economic, human-politics, and public relations. Goals of the upcoming year are approved by the Board of Directors, who also analyses the fulfilment of the previous year's goals. For determination of goals both qualitative and quantitative methods and parameters are used. All the efforts of the entire plant staff have resulted in Paks successful operation with steadily improving levels of availability, reliability, and safety.

HU.4. MANAGING AND WORKING AT PAKS

The plant management is actively involved in improving plant performance. There are several areas of management activities.

Membership in international organizations: After the political changes in 1989, the plant started to more actively participate in international organizations, such as the IAEA. Since that time, the plant has developed international co-operation, has established contacts with western nuclear power plants, and has been participating in a number of European projects. In connection with accepted western experience and standards, the plant has tried to improve its safety culture and level of performance.

Improvements in working environment: Another of important factor affecting plant performance is the working environment. During the 1990s, plant management has succeeded in maintaining a high level of housekeeping at the plant, many of plant buildings and offices, including operator rooms have been adapted and refurbished and equipped with computers.

The outdoor spaces of the plant have been landscaped. The overall appearance of the plant has significantly improved. Between 1990–1995, a plant safeguard system was established, which significantly improved the plant security and indirectly influenced plant availability.

HU.4.1.1. Organizational structure

Paks is an organizational unit of the operating utility — the Hungarian Power Company Ltd. The plant's organizational structure is divided both vertically and horizontally. The vertical structure is formed by two managerial levels: (a) the plant top management (directors and deputy directors) and (b) departments (specialised executive units). The departments are further divided into sections. The horizontal structure consists of sectors (activity areas) managed by individual deputy directors. The following chart shows the actual organizational structure of the Paks NPP.

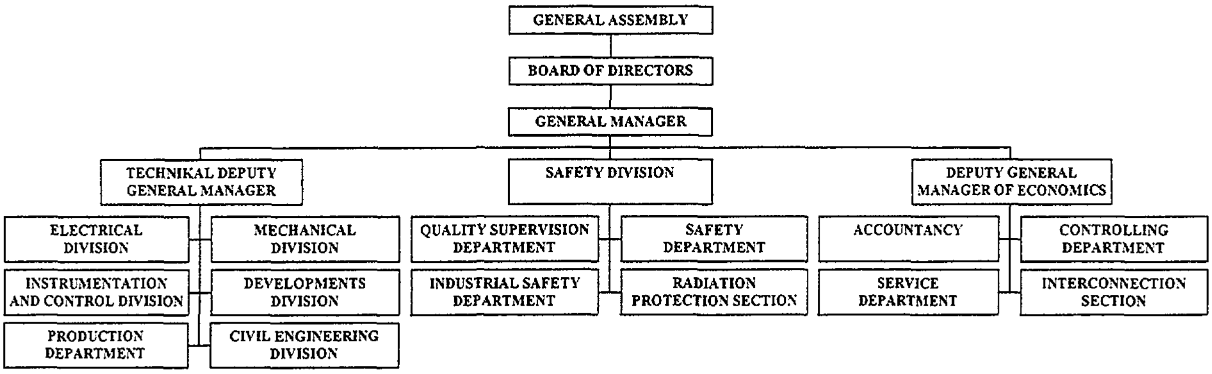


FIG. 13. Organizational chart.

Plant directors are responsible to the utility executive board. The technical director is responsible for management of technology (operation, nuclear safety, maintenance), while the finance director manages the finance and administration area (business and personnel matters and services). Each of these two directors has deputy directors responsible for individual sectors. The deputy directors for nuclear safety, operations, and maintenance report to the technical director. The other two deputy directors report to the finance director. Each deputy director manages an assigned sector vertically divided into departments. Particular tasks of the departments are performed by the sections. The head of each organizational unit is in charge of the unit's performance.

The plant management uses the following organizational tools to implement its policy: director's orders and decisions, management standards (regulations, rules, programs), guidelines (management procedures or methods) at the level of top management, and quality handbook and program procedure at the level of sections. As a management tool, directors also use the management meeting, quality committee, emergency team and other advisory boards, committees and working teams.

The most characteristic statement of the current period is that Paks, like the country itself, is in a transition period. This transition can be seen in changes in Paks ownership:

1st stage (1983–1992): During the socialist period, the owner was the Hungarian government.

2nd stage (1992–1994): First steps in the transformation to a joint stock company. Shares were held in the following proportions:

- Hungarian Electric Energy Board, 49.7%
- Holding Company of National Properties, 50%
- Local governments, 0.3%

3rd stage (1994–1997): Stockholders of the plant are

- Hungarian Electric Energy Board, 99.7%
- Holding Company of National Properties, "Gold stack," Local governments, 0.3%.

Responsibilities of each management level are clearly determined, but high level decisions are referred to either the technical board or the investment board. Financial decisions depend on the level of expenditure: expenditures below 10 MHUF are the responsibility of the general manager, expenditures above 10 MHUF are the responsibility of the investment board, and expenditures above 1 BHUF are the responsibility of the Board of Directors of the Hungarian electric energy board.

Further, the organizational structure has changed twice between 1990–1995. Both changes were initiated by the owners of the power plant. The first change was made in 1992 when the original organizational model was transformed and operation, maintenance, safety control, and technical activities were separated. The second change was made in 1994, when maintenance and operation were concentrated and the privatisation was started in the company. Goals of this change were (1) to reduce the number of permanent employees at the plant, (2) to better use of the maintenance potential between refuelling outages, and (3) to improve the quality of work.

Considering this experience, the economical and technical background of the country has had an effect on the organizational structure of the plant. These reasons are (1) there were no technical institutes, so the most qualified experts worked at Paks; (2) keeping qualified engineers and technicians has been very important because Hungary is not a large labour; and (3) earlier plans to construct additional units are still being considered.

All of these factors led to high levels of employment in comparison with other plants (3000 permanent employees and 800 full time contractors). The resistance against "management induced" privatisation is large. To produce electricity without major conflicts (worker strikes) on the same level of production and safety has not been easy.

HU.4.1.2. Strategy and goals

Paks management operates the plant with the requirements of the owners and knowing the technical limitations. A general goal is to maintain the competitiveness of the plant operating safely with a high availability. This general goal is transferred into particular goals for the following areas: production, safety, economic, human-politics, and public relations. Goals of the upcoming year are approved by the Board of Directors, who also analyses the fulfilment of the previous year's goals. For determination of goals both qualitative and quantitative methods and parameters are used. All the efforts of the entire plant staff have resulted in Paks successful operation with steadily improving levels of availability, reliability, and safety.

HU.4.1.3. Management involvement and communication

To facilitate the everyday communication, an e-mail system, as a part of the plant internal computer network has been implemented. The system is widely used and enables a quick and effective communication between other institutes and utilities. This communication channel was used extensively in the AGNES project (advanced general and new re-evaluation of safety) and the licence renewal process between Paks and the involved partners.

Another tool of management communication with the plant staff is the regular management meetings followed by cascade briefings. Every Monday, the plant directors meet their deputies, plant representatives, and other invited guests. On the following day, the deputy directors meet their inferior section heads, who meet with the pertinent department heads and team leaders on the same day or on Wednesday. The meetings take place during working hours and last usually 30 to 60 minutes. Important technical and economic information originates in such decision making forums as the Technical Board and the Investment Board. Problems are solved in maintenance meetings, which are the main source of information exchange between employees and management.

A new form of technical information transfer, used since 1994, is the "thematic meeting," where topics are discussed with the participation of any interested employee and members of the management. The topics can be related to technical improvements, preparation for conferences, or technical and economical activities. There are also informal discussions and regular "production meetings."

To keep plant personnel informed, there is a weekly internal newspaper, "Heti Tájékoztató." Articles in this newspaper are prepared either by the newspaper staff or are provided by plant managers. Topics include all areas of plant activity, such as new investment projects, performance indicators, intended changes, questions and answers, sports and cultural information, news from international nuclear installations, etc. All important information and brief newspaper reports are put on light boards in the dining hall during breakfast, lunch, and dinner. In addition, a daily newspaper monitor focusing on industry news is prepared and posted on a notice board in the administration building's entrance hall.

A new way of information collection is the use of specialized audit companies. Paks management uses these services to test the effectiveness of some management decisions to become informed regarding employees' opinion of the management.

There have been significant improvements in public relations. The plant has established a new information centre with presentations of the plant, its policy, and its effects on the environment. A more open and friendly attitude toward the surrounding villages and their representatives helped gain their confidence and consent to the construction of an interim spent fuel storage facility on the plant site in 1996. This headed off possible shutdown of the plant because of a lack of spent fuel storage facility. The information centre collects all information released by the media in connection with Paks and other nuclear installations. The centre is also responsible for the monthly publication, *Atomerõmû.* This publication contains reports with plant employees, economic background information, reports of employees returning from foreign technical visits and conferences, sports results, etc.

HU.4.1.4. Managing quality

A quality management system was introduced at the plant between 1991–1996. About 300 plant employees have been trained and licensed in ISO and NUSS Standards and TQM principles. The plant has been performing internal audits since 1991. Approximately 10 internal audits per year are conducted. Since 1995, the plant has been performing external audits of contractors. So far, 52 plant contractors and suppliers have been audited. The ISO

9000 licence requirements for contractors have not been established yet. For the time being, however, about 20% of contractors are ISO 9000 licensed.

HU.4.1.5. Relationship with contractors

The overall plant policy is to reduce its permanent employees and to increase the involvement of contractors in various plant activities (investment projects, maintenance, engineering services, cleaning, etc.). The contractors have not been integrated into the plant's structure. Because some of the contractors are privatised plant departments, their staff is highly qualified, trained, and experienced. In addition to the high quality of contractor's services, Paks requires contractors to have a licence and a QA handbook. Regular audits of the contractors are performed by the plant. There are no limitations of the contractors' activities. There are no special guidelines for the outage contractors; they must comply with the plant regulations.

Contractors are responsibility for providing adequate training to their employees and for establishing QM programs, including staff training. For these purposes, the contractors can also use the utility's educational and training centre on a commercial basis. The plant communicates its objectives and operation philosophy to the contractors on training days organised for permanent contractors. In addition, the contractors are provided with management standards, orders, decisions, guidelines, and regulations.

HU.4.2. Personnel

HU.4.2.1. Personnel characteristics

Figure 14 shows changes in number of employees from the above mentioned organizational changes and compares these changes with the power productivity per employee.

Figure 15 illustrates the composition of the Paks staff.

Figure 16 shows the educational structure of the plant staff. There has been indicator a decrease in number of workers with lower levels of education and an increase in the portion of university educated personnel. This high level of general education is one of the important factors influencing the plant availability. Except for the education requirements, the personnel have to be in good physical and mental condition, which is checked by a medical and psychological examination when starting the job. A preventive medical examination is then repeated annually. The licensed operators, in addition, must pass psychological tests every two years.

HU.4.2.3. Personnel development and training

Another important factor influencing plant availability is the high level of personnel qualifications. On the other hand, ageing of personnel must be taken into account, because the average age of the company is above 40 years. Therefore, new employees must be trained. The plant has established a comprehensive training program divided into basic and refreshing training. Basic training is composed of six specific categories according to individual plant professions (managers, licensed operators, system engineers, supervisors, equipment operators, etc.). Each particular training category consists of training modules (theoretical education, practical training at the plant, simulator training, preparation for final exams, etc.).

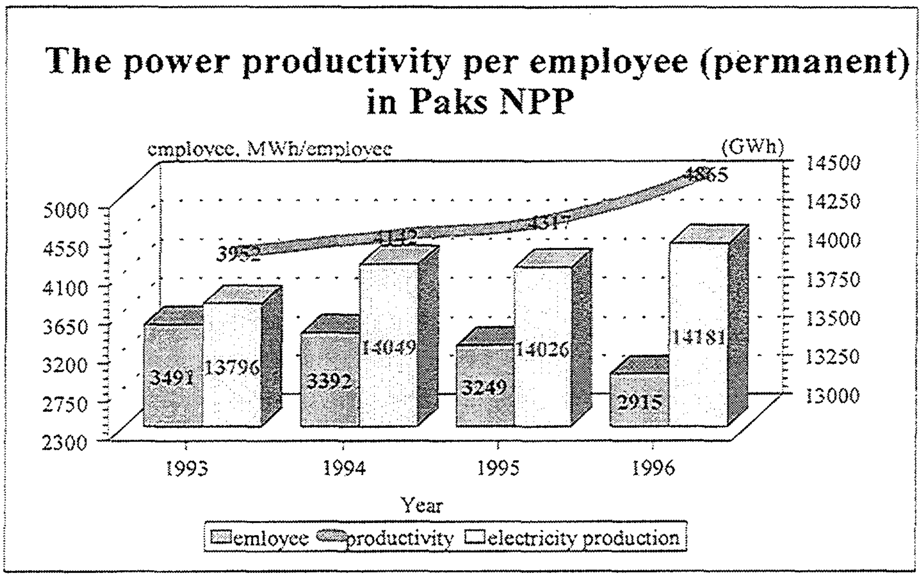


FIG. 14. The power productivity per employee (permanent) in Paks NPP.

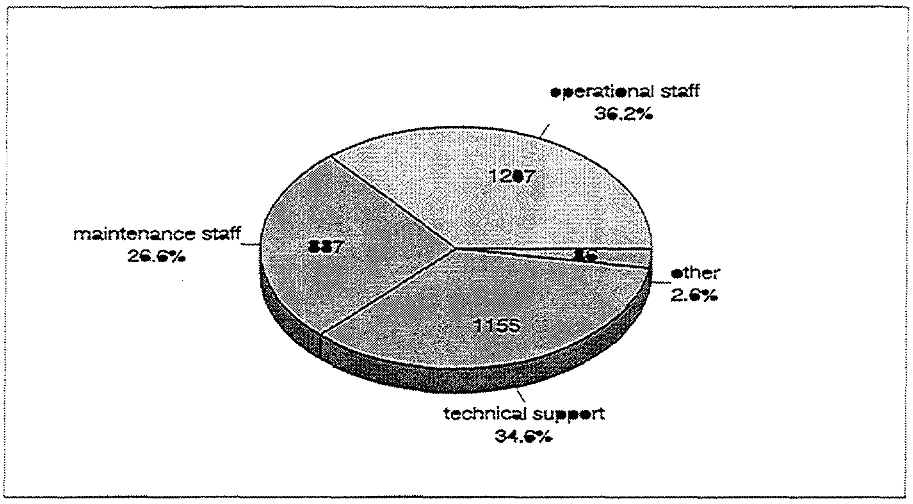


FIG. 15. Paks NPP staff in 1995.

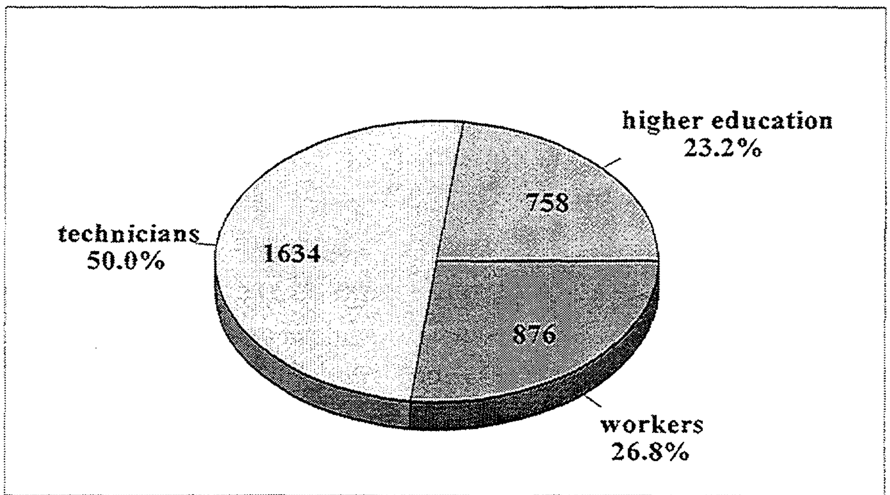


FIG. 16. Personel structure according to their education.

The basic training for licensed operators, for example, consists of 10 modules, lasts for 66 weeks, and is completed by final exam. Also, after a month of on-the-job training, the operators must pass a state exam to obtain a licence.

The main part of the operations personnel's refreshing training days includes main plant modifications, procedure changes, and operational experience feedback. The period is one training day every six weeks. The other plant personnel's training days take place over a longer period. Licensed operators also complete a week of refreshing simulator training every six months. Other selected staff members complete various specialised professional refreshing courses (electricians, crane operators, welders, etc.). Plant personnel are annually trained in fire protection and industrial safety. Managers and other selected personnel participate in management courses and QA training. Many employees take part in foreign language or computer courses. Although the overall trend in training budget is increasing, the ratio of the training budget to the OM budget is low when compared to the rest of the industry.

Due to the high plant personnel qualification, the number human factor-caused events remains low and is decreasing. With an increasing portion of contractors, however, the number of events caused by contractor's personnel has risen.

HU.4.2.3. Personnel behaviour and attitudes

Personnel attitudes are an important factor contributing to high plant availability. Due to very careful selection of personnel and a relatively long, demanding training process, only quality individuals can successfully complete all the tests and exams. In addition, successful candidates also obtain a solid and broad knowledge of the plant. This helps develop a feeling of responsibility and ownership attitudes toward the entrusted equipment and results in a high level of performance. So, for example, equipment operators, electricians, and I&C technicians are not narrowly focused, but also notice other equipment and report to each other the deficiencies and faults discovered on their walk-rounds.

HU.4.3. Working practices

HU.4.3.1. Plant status control

The basic means of plant status control are walk-arounds. According to the pertinent control procedure, the main control room (MCR) licensed operators (besides continuously monitoring equipment) carefully check all gauges, displays, alarms and control lamps, and write down selected plant parameters on record sheets. Once a shift, they visit and check the emergency control room. Reactor operators walk through the reactor control and protection systems rooms next to the MCR. The equipment operators, electricians, and I&C technicians check their equipment every two hours, checking for anomalies and recording selected important parameters.

If a problem is discovered, the pertinent staff member (MCR or equipment operator) reports it to a responsible operations supervisor, who prepares a work request, which is then passed to the a responsible maintenance co-ordinator. The co-ordinator prepares a clearance sheet indicating the boundary of clearance, tagouts, and equipment to be de-energised. The clearance itself is then performed by operation personnel. Once the clearance implementation is confirmed by the responsible operations supervisor, the co-ordinator assigns the work to a specialised permanent contractor and keeps track of the subsequent activities until the clearance is removed and repaired equipment is returned to operation. All the necessary information is entered, transferred, and logged through the co-ordination network. Also, MCR operators record all clearances in their log and transfer this information at shift turnover; all de-energised components are recorded in the power operated equipment card file. Operations supervisors and senior reactor operators have regular access to the Co-ordination Network to obtain information of the status of all active clearances.

Another method of plant status control is the regular surveillance testing of safety systems. These tests are performed according to an approved schedule, mainly on a monthly or quarterly basis. Safety system status (component position) upon completing the test is checked by using check lists, making sure that the system had been returned into a standby position.

A minimum of lighting alarms and annunciators is the sign of normal and safe plant operations. Therefore, the plant policy is to minimize the number of permanently lit alarms, which has been established as one of minor upgrading projects. Once an alarm actuates, the control room operator sends a field operator to the spot to determine the cause. Then appropriate measures are taken to clear the alarm or to solve the problem.

HU.4.3.2. Operations

HU.4.3.2.1. Operating procedures

Most of the current operating procedures were delivered with the equipment from the former Soviet Union and translated. A majority of them have been revised and amended several times. The revisions and amendments are performed by the Operations Department. The department collects and amends the procedures with all information on plant modifications, lessons learned from operating experience, and operators' comments. The currently valid procedures are not symptom oriented.

HU.4.3.2.2. Operating aids

A variety of operating aids is used at the plant both in the MCR and at the field equipment locations. The MCR operators are supported by colour coding safety system panels. The SI pump and control switches are covered by transparent plastic boxes. Protective covers are placed on turbine generator trip buttons. All equipment control switches are grouped and colour coded according to individual systems. A simplified flow diagram with green, red, and white lamps is provided on a board above system control panels to help operators quickly check the plant status regarding component operation and position.

Field operators are aided by pipeline colour coding (red strips on steam pipelines, grey on demineralized water, green on service water, blue on service air, etc.). All components are consistently labelled by firmly attached metal plates containing unique component code, arrow shaped plates attached to pipelines indicate flow direction and type of medium (water, condensate, etc.). All permanently secured components (open or closed valves) are locked and tagged.

HU.4.3.3. Maintenance

HU.4.3.3.1. Maintenance policy

Plant maintenance policy follows from the overall strategy of the MMM and is regulated both by international and national standards. The strategy is to operate with a minimum number of outages that are as short as possible. It is based on methods of predictive, preventive, and corrective maintenance. Material and financial plans of maintenance come directly from this policy. They are divided into long term (five-year), one-year, monthly, and daily plans. Planning and work management are supported by a Hewlett-Packard information system adapted to plant's conditions and six levels of urgency are used for prioritising work. The maintenance program is conceived so that a majority of the work is carried out during refuelling outages. This limits the potential for reducing length of refuelling outage, which is one of the main objectives of maintenance management and co-ordination.

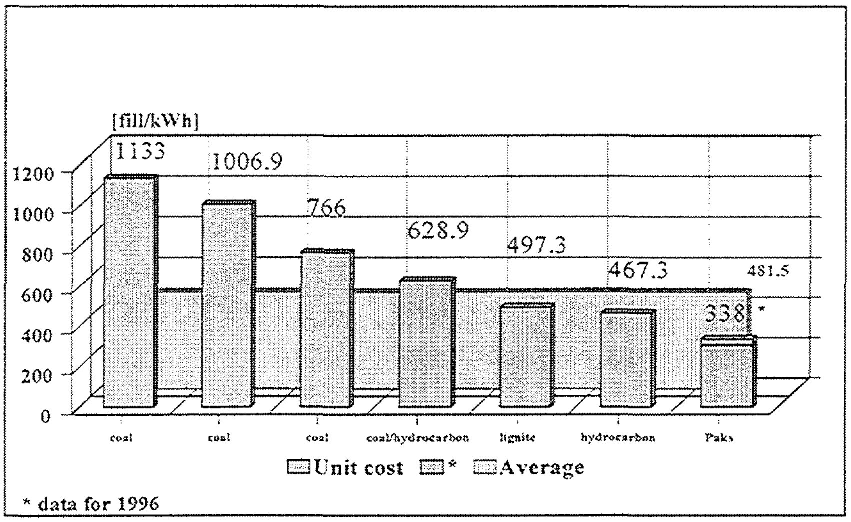


FIG. 17. Cost of electricity production for different Hungarian power producers (January–October 1996).

HU.4.3.3.2. Planning and scheduling

For maintenance planning, a computer system with work order system software that has been developed by plant specialists. The system is used for work order management. It consists of several modules, including an equipment catalogue containing related equipment data (technology, safety issues, classification, etc.). The equipment maintenance history is available from 1989, when the system started. The work-order management module contains standard work orders (templates for recurring activities, including equipment inspection, diagnostics, overhaul, replacement, etc.) and induced orders (manually generated ones) that must receive approval. Work orders enter the maintenance scheduling system one month before a unit refuelling. The software enables a detailed activity scheduling with the integration with operation, and the optimisation of activities according to available capacities. Work orders related to particular equipment are collected in "working packages" for each phase of planning, preparation, completion, and documentation. The network allows sharing information of clearance implementation or removal and the opening and closing of a work order. It is used for an efficient communication between co-ordination and maintenance workers to facilitate flexible changes according available capacities. This information is transferred to a daily maintenance plan that contains detailed information of a particular day's maintenance activities.

HU.4.3.3.3. Procedures

There is a strict requirement that contractors performing maintenance use specified work procedures approved by the plant. Because of recent legal changes in Hungary, revisions and approval of work procedures must also be prepared.

HU.4.3.4. Technical support and other activities

After the political changes in Hungary after 1989 and because of increasing requirements by the international community to revise and improve safety at nuclear power plants of Soviet design, Paks began its upgrade program. This was started in 1986 in response to the Chernobyl accident and was based on a government decision No. 309 of November 1986. A prerequisite of successful program implementation has been to evaluate the Paks' design, identity weaknesses, and propose adequate solutions. This was done by using the following sources of information:

(1) IAEA missions
   - an OSART mission at the plant in September 1989 focused on the plant's operation
   - a Re-OSART mission in November 1991 focused on the plant's maintenance
   - an ASSET mission focused on operating experience feedback

(2) Information received through WANO information exchange programmes

(3) Joint activities with other WWER-440 plant operators ("WWER-440/213 Club", "Users Group")

(4) Plant audits
   - an internal audit was performed by the plant in 1994 to evaluate the plant design from viewpoints of the plant's nuclear safety and reliability, availability, maintainability, lifetime and spare parts' procurement
   - an external audit was performed by the ENAC consortium to evaluate the plant's design from the standpoint of international standards

(5) Supporting analyses, IAEA and PHARE projects:
   - PSA study, level 1 completed in 1995
   - IAEA consultants meetings in 1994 and 1995
   - IAEA programme "Safety Assessment of WWER-440/V213 plants" with the Bohunice V-2 as the reference plant
   - results of equipment qualification assessment

Based on the findings and recommendations of the above missions and assessments, the following areas of problems have been identified

- design of WWER-440/213 plant differs from the designs based on IAEA standards, which can adversely affect the potential for continuing safe operation and lifetime extension
- there may be limits in component lifetime due to their overall reliability and maintainability
- limited availability of spare parts and frequency of their need may adversely affect plant availability

Considering the above findings and conclusions, a plant upgrade project has been developed with the following objectives:

- modify the plant technology according to the current legislative requirements considering prospective licence renewal
- upgrade the obsolete plant equipment and structures to prolong their operability, reliability, and maintainability
- make the operation of all plant possible through the designed lifetime and create conditions for the lifetime extension
- facilitate a cost effective increase in rated reactor power

To achieve this, the project has been divided into several stages:

Stage 0 — Plant make-up program (1986–1995)

This part of the upgrade program survives from the efforts following the Chernobyl accident. It includes solving immediately pending problems identified by operating experience. A number of problems have also occurred during regular testing programs. Most of the activities in this stage have been completed and have contributed to improving reliability of plant components. This includes the successful modification of pumps in the high pressure injection system and central pump station.

Solutions to the above mentioned problems identified by internal and external plant evaluations have been further divided into subsequent stages.

- **Stage 1 — Urgent actions (1996–1999)** — implementation of various partial projects proposed as necessary by plant departments.

- **Stage 2 — Plant upgrading (2000–2006)** — actions based on requirements, recommendations, and suggestions following from the above mentioned missions, assessments, and audits.

- **Stage 3 — Plant backfitting (2007–2010, or 2016)** — activities aimed at plant life extension, including replacement of some key components.

Annex E: WOLSONG CASE STUDY

KR.1. PLANT DESCRIPTION

Wolsong Unit 1 (Wolsong) is located in the southeast of the Republic of Korea, midway between Yongil and Ulsan bays. It lies about 30 km north of the city of Ulsan. In January 1975, KEPCO concluded an agreement with Atomic Energy Canada Limited (AECL) for the design, supply, construction, testing, supervision of commissioning, and initial operation of a 600 MW(e) CANDU-PHWR. Wolsong entered commercial operation in April 1983. The construction period was 62 months from February 1978, when the construction permit was granted. Wolsong Units 2, 3, and 4 are being constructed on the same site and will be placed in-service in 1997, 1998, and 1999. They are 700 MW(e) PHWRs similar to the Wolsong Unit 1. In 1999, the Wolsong site will have a total capacity of 2779 MW(e), representing a considerable portion of Korea's nuclear capacity.

Wolsong is designed for commercial base load operation. It has a turbine generator set delivering a net electrical output of 628.6MW(e) and a nuclear steam supply system from a CANDU-PHWR reactor. This type of reactor uses heavy water as a moderator and coolant. The fuel is natural uranium in bundles that can be loaded and removed from the reactor during normal operation. The turbine cycle is similar to that used for other plants of this type. This consists of a twostage steam driven turbine, including a water extraction system. The CANDU-PHWR has small diameter fuel channels that extend the life expectancy of the reactor and allow easy accessible for repairs.

Wolsong's thermal cycle consists of natural uranium in 380 horizontal zirconiumniobium alloy pressure tubes, four reactor coolant pumps and piping, a heavy water to light water steam generator, a turbinegenerator set, a main condenser, and feed water pumps and piping. In particular,

- The cylindrical core consists of 380 fuel sites in a square lattice pitch of 286 mm and an overall core length about 606 cm and radius 314 cm. The average fuel burnup is 180 MW.h/kg U.
- The fuel bundle has 29 UO_2 pellets stacked end-to-end sealed in a zirconium alloy sheath. The length of the fuel bundle is 495 mm with overall weight of 23.67 kg. The weight of uranium is 18.82 kg. The fuel bundles in adjacent channels in the reactor are fuelled in opposite directions. This is known as bi-directional fueling.
- Two fueling machines refuel the reactor by loading and unloading fuel at the reactor face. The machines are normally operated remotely from the control room.
- The Primary Heat Transport System is designed to circulate 7.44 Mg/s of pressurized heavy water through the coolant tubes at 10.0 MPa to remove heat. The heat is transferred from the heavy water to light water in the steam generator. The pressure of the reactor outlet headers is controlled by a pressurizer connected to the outlet headers at one end of the reactor.
- Four identical boilers (steam generators) transfer heat from the heavy water coolant on the boiler primary side to raise the temperature and boil light water on the boiler secondary side. The boilers consist of an inverted vertical U-tube bundle installed in a shell. The primary side of the boilers is designed and manufactured to the requirements for Class 1 components under section 3 of the ASME boiler and pressure vessel code. The secondary side is Class 2.

The major parts of the moderator system are the calandria, heat exchanger, and pumps that circulate heavy water through the system to remove heat. The system maintains the chemical purity and the activity level of the heavy water. Helium covers the free space in the moderator heavy water system. The helium flow through the calandria head tank is approximately 1.4–2.4 l/s (STP). This flow is sufficient to maintain the concentration of deuterium gas (D_2), which results from the radiolysis of D_2O in the gas space below four percent.

The reactivity of the reactor is controlled by five methods: (1) During the normal operation, the liquid zone control assemblies are used to adjust the flux level in any one of 14 zones in the reactor. (2) Twenty-one adjuster rods are provided to optimize neutron flux for reactor power and fuel burnup, and provide excess reactivity to overcome buildup of Xe–135 following power reduction. (3) Four solid control absorbers are provided to adjust the flux level at times when greater reactivity rate or depth is required than that provided by the liquid zone control system. (4) Moderator poison control is provided by solutions of boron and heavy water and gadolinium and heavy water. $GdNO_3$ is used to compensate for the absence of xenon during the start of the reactor. Boron is used for long term reactivity shim control. (5) After equilibrium conditions have been achieved, continuous on-line refueling is the main means of long term reactivity control.

The turbine is a tandem compound unit directly coupled to the generator. Turbine instrumentation monitors conditions such as bearing vibration and eccentricity. The 3-phase generator is rated 680 MW(e) at 24kV with a power factor of 0.85 and frequency of 60 hz. Other characteristics of the plant are

- Electrical power is generated at 24KV and transformed to 345KV by the main transformer for the transmission grid. Power supplies for the service and instrument loads in the plant fall into four categories, based on reliability requirements.
- The station is fully controlled from the main control room and is regulated by a dual digital computer system. Computers are employed for station control, for data acquisition and data display, and for fueling machine control. Some of the typical control functions are reactor power regulation, plant load control, steam pressure control, neutron flux distribution, channel temperature measurement, and fueling machine control.
- Protective channels and instruments are used to shutdown the reactor after a fault in plant operation. System and equipment control lines operate in triplicate or in other multi-channel arrangements. They are arranged on trip lines that "trip" on a two out of three basis.
- The station process and service system includes a condenser circulating system, a recirculated cooling system, a raw service water system, a fire water system, a domestic water system, a waste disposal system, a HVAC system, a drainage system, a compressed air system, and a gas system.

KR.2. HISTORICAL PERFORMANCE

Wolsong has been operating successfully since commercial operation in April 1983. Internationally recognized performance indicators (PRIS, WANO) are analyzed every 3 months and reported to the plant manager. (See attachments.) These performance indicators are compared with the other CANDU 600MW(e) plant every year (Point Lepreau, Gentilly-2, Embalse, etc.).

A lifetime capacity factor of 85.2% and an availability factor of 83.9% have been achieved. Best efforts are being made to increase the availability factor by (1) reducing the plant transients caused by human error and component failure; (2) shortening planned outages; (3) improving thermal efficiency; and (4) minimizing the effects of plant aging.

Regarding the duration of planned outages, the channel spacers in CANDU reactor were found to have moved following installation in mid-1980. This movement could allow the pressure tubes to contact the calandria tubes, accelerating hydrogen absorption in the pressure tubes. A new technology was needed to locate and reposition these spacers in all CANDU reactors. Because of spacer repositioning, the duration of planned outages has increased during the last 6 years. The duration of outage and the quantity of channels inspected and spacers repositioned have been

TABLE 1. DURATION OF OUTAGE VERSUS NUMBER OS CHANNELS INSPECTED

	1990	1991	1992	1993	1994	1995
Outage duration (planned/actual)	45/42	31/37	53/53	N/A	62/62	59/62
SLARette: Spacer location and repositioning (= 12 hours/CH)	-	-	-	-	3 CH	48 CH
CIGAR: Channel inspection and gauging apparatus for reactor (= 24 hours/CH)	11 CH	-	19 CH	-	14 CH	-
Scrap sampling	-	10 CH	10 CH	-	2 CH	-

Regarding fuel management, the most significant measure of core performance is the maximum channel power rating. Locating and removing defective fuel during normal operation affects the plant availability factor indirectly. In CANDU reactors, refueling is performed every day and measured by the average fuel burnup rate. The rate of refueling (bundle/FPD) and the amount of defective fuel are relevant performance indicators.

Heavy water management is very important in CANDU plants because it is expensive and can become radioactive (tritium) from neutron absorption. Strict controls and measurement are needed to reduce the operating cost and radiation level. The program for heavy water management includes heavy water recovery after escape from the primary enclosure and from miscellaneous sources, such as samples, drainage, and vapour recovery. To increase recovery efficiency, Wolsong has completed (1) modification of the heavy water collection system; (2) computerization of leak monitoring; and (3) the development of leak detection tools.

KR.3. OVERVIEW OF THE WOLSONG CASE STUDY

Wolsong is the only plant among those described in the case studies where there is an older, operating NPP and an active construction program for three newer, larger reactors. Therefore, Wolsong management must carefully allocate experienced personnel to the operations and construction programs. Also, because Wolsong is refueled during operation, maintenance outages involve hiring fewer specialists than at other plants. This allows a more consistent relationship with contractors. These details are outlined in sections KR.4.1.5.1. Contractors during operation and KR.4.1.5.2. Contractors during outages. In its attempt to improve availability at Wolsong 1 and prepare for operating Wolsong 2, 3, and 4, while minimizing potential hazards, Wolsong management promotes

- Prominent management and a high degree of teamwork
- Good relationships with contractors
- Investments to reduce the influence of aging
- Improvements in the employees' knowledge

KR.4. MANAGING AND WORKING AT WOLSONG

KR.4.1. Management practices

Goals of the plant manager in the operation of Wolsong unit 1 include (1) reduction of plant trips caused by human error and equipment failure; (2) enhancement of operations and maintenance; (3) improvement of thermal efficiency; (4) minimization of plant aging; and (5) controlling environmental radiation. Responsibilities of the plant manager for the commissioning of Wolsong unit 2 include (1) system takeover from the construction team, (2) commissioning tests, and (3) recruitment of operation and maintenance personnel.

KR.4.1.1. Organizational structure

At the Korea Electric Power Corporation (KEPCO) there are 606 departments with a total of 37,353 employees as of December 31, 1996. At Wolsong there are 11 departments and 492 employees. There are 8 departments at Unit 1: mechanical, electrical, I&C, power generation, technical, radiation, chemistry, and fuel handling with 283 employees. There are 3 departments, engineering affairs, technical support, and power generation with 209 employees for Unit 2 commissioning. The productivity per permanent employee has been

TABLE 2. PRODUCTIVITY PER PERMANENT EMPLOYEE

	Average	1990	1991	1992	1993	1994	1995
Permanent employees	249	255	250	248	258	247	240
Generation (GWh)	5263	5106	5417	5177	5993	4912	4914
GWh/employee	21.14	20.02	21.67	20.88	23.23	19.89	20.73

KEPCO's nuclear power generation division consists of 15 departments and 126 employees. Located at KEPCO's head office, it directs and supervises 4 nuclear sites. Its main tasks are the operation and maintenance of nuclear plants, facilities improvement and safety security, training for nuclear employees, core management, planning for radiation emergencies, radioactive materials management, environment control, licensing and commissioning new plants, and public relations.

At Wolsong there have been some minor organizational changes since 1990. Following the policy of KEPCO head office for improving plant performance, the general affairs department was abolished and the mechanical department took over its function. For improvement of safety and the enhancement of operators' capability, the number of shifts in the operation department was changed from 5 to 6. For securing specialization and enhancing plant performance, 4 new sections were established. They were an environment chemistry section in the chemistry department, an electrical equipment section in the electrical department, a mechanical inspection section in the mechanical department, and a software development section in the technical department.

There are two kinds of management evaluation systems. One is focused on new managers and the other on plant performance. To get accustomed promptly to their new environments, new managers (at levels higher than deputy general manager) make action plans to be accomplished in the first 100 days. The KEPCO management team evaluates the result. To overcome the inherent inefficiency of a monopoly and government owned utility, an internal competition system has been introduced. A checklist is used to rank the performance of the six competing nuclear business units. At the end of the year, various incentives are given according to rank.

KR.4.1.2. Strategy and goals

A ten-year master plan has been established. Based on the analysis of current status and the internal-external management environment, this plan sets long term goals and describes political guidelines. Detailed action items are prepared in phases. The master plan is revised every two years and is the basis for each year's business plan, the short and medium-term investment schedules, and long term plant upgrade plan.

During the next ten years, there are four sets of goals. First, safety has the highest priority and is to be maintained within an agreed upon safety culture. Second, perfect radiation management, high reliability of safety-related facilities, and good environmental protection results are pursued. Third, the working area should be as clean and comfortable as possible. Fourth, there should be a 95.81% average capacity factor, 25 to 30 days of scheduled annual outage and minimum site electricity consumption. To achieve these goals, modification, backfitting, and upgrading of the system will be continued and total quality control will be applied to all areas. Also, these goals require the best operation and maintenance technologies through good personnel and self-reliance. An expert team will be organized for plant support. The team will be dedicated to acquiring the core technologies specified in the master plan and exploiting international cooperation.

Also, human performance is the most important factor in plant operation. Performance is optimized when company goals and motives for personnel development coincide. The "personnel motivation program" encourages attendance of domestic and overseas conferences, enrolling in technical colleges and special institutes, and suggestions of good practices. Also, employees are encouraged to use the job proposal system. Employees whose proposals result in performance improvements receive bonuses and opportunities to visit well performing companies overseas.

KR.4.1.3. Management involvement and communication

Each manager periodically checks the status of on-going actions to ensure management objectives and goals are successfully accomplished. Wolsong management checks and evaluates plant progress on a monthly and quarterly basis. KEPCO compares plant operations through evaluations. For nuclear power plants, 15 items (including enhancement of availability and preventive maintenance to avoid plant trips) are selected as station management's objectives. Some problems in special areas, which are critical to reach the goals and objectives, are handled through a task-force team consisting of specialists in a particular area. The team is authorized to solve problems and get financial support. In addition to task-force teams, UTEGs (unit technical expert groups), established through the company's computing network, are utilized.

Management objectives and plans are presented through meetings and communications. Common items applying to all employees are communicated between top manager and employees through the computer networks (LAN, WAN, and Internet) and the job proposal system. Through regular meetings with staff in the morning, the status of plant or certain projects and managerial problems are discussed. The contents of that meeting are delivered to each department. Regular meetings are held on a daily, weekly, monthly, and quarterly basis. Irregular meetings are held when special circumstances occur. These include (1) irregular meetings with plant manager (one or two times a year) and (2) meetings between departments and plant manager (once a year per department). Sometimes athletic programs and self-denying spirit programs are held to encourage harmony among employees and for mental and physical training. For improving relations with local communities, the internal newspaper, Yang Ji, is published and distributed.

KR.4.1.4. Managing quality

A reduction of facility's transient and unavailability rates has been achieved through systematic quality control activities. The QA department is responsible for the control of QAPM implementation, planning of TQM, witnessing safety-related maintenance and tests, and the in-depth surveillance of recurring quality problems. The number of inspections averages 25 per year by internal (site), external (head office), and regulatory agencies (MOST, KINS). The number of NCR/CAR issues reached 45/7 items in 1995, continually increasing since 1990. Inspection of tools and materials has been done more than 10 times per year. The number of monitoring and supervising activities is approximately 600 per year. Quality inspection activities are being transferred to operation, maintenance, and support crews, who are trained and qualified as authorized inspectors according to Quality assurance procedures (QAPs).

All employees must take a mandatory quality training course (more than 4 hours per year) given by the QA department. Training courses also include QATM, ISO 9000 series, quality improvement (QI), etc. There are five courses in quality control given at Wolsong.

An ISO 9000 license is not required for Wolsong's contractors and suppliers because QAP has been established and operated on the basis of 10 CFR 50 App. B ASME NCA 4000 and NQA-1, CSAN286.5 ISO 9000 series. All contractors conduct their own quality assurance activities according to the QA procedures approved by KEPCO.

KR.4.1.5. Relationships with contractors

KR.4.1.5.1. Contractors during operation

There are 4 major contractors for maintenance and engineering:

- KPS (Korea Power Service) is the maintenance contractor for mechanical and electrical systems and equipment. They are an independent maintenance company and have 176 employees at Wolsong during normal operation. During outages, the maintenance organization is changed to a temporarily enlarged organization. Skilled persons are dispatched from other plants and labor is hired from the local area.
- Samchang Engineering Company performs I&C equipment maintenance, except on the safety and major process systems (done by KEPCO). There are a total of 26 employees from Samchang for Wolsong, divided into four subsections. (Since 1991, Samchang has performed minor maintenance on the drainage system, HVAC, and domestic water system.)
- Iljin Company is responsible for radiation decontamination and assisting health physics work. They have 58 employees during normal operation. (Iljin entered into its first contract with KEPCO in 1995. Hanil Nuclear Co. had performed this work for three years prior to Iljin accepting the contract.)
- KOPEC (Korea Power Engineering Company) does modifications engineering. There are 8 employees at Wolsong.

Type of work performed includes (1) daily corrective maintenance, (2) planning and implementing the preventive program, (3) call-ups, and (4) assistance to KEPCO on request.

The work schedule and the amount of work done is confirmed and checked by KEPCO through work order. The numbers of contract employees are

TABLE 3. NUMBER OF CONTRACT EMPLOYEES

Company	1990	1991	1992	1993	1994	1995
KPS	171	168	177	170	170	167
Samchang	13	13	523	25	25	26
Iljin	16	17	19	22	22	40
KOPEC	8	8	8	8	8	8
Total	208	206	218	232	225	241

Current percentages of KEPCO employees and contractors are

TABLE 4. PERCENT OF KEPCO EMPLOYEES

Department	KEPCO employees	Percent	Contractor employees	Percent
Mechanical	33	13.8	85	36.0
Electrical	19	7.9	23	9.7
I&C	17	7.1	21	8.9
Radiation Protection	23	9.7	35	14.8
Other	147	61.5	72	30.6
Total	239	100.0	236	100.0

There are major communication links between KEPCO-Wolsong and the contractors via WAN and LAN. The exchange of mutually interesting information and invitations to Wolsong meetings are sent via email. The daily work plans, which contractors submit to the related department include (1) work in progress, (2) maintenance problems and solutions, and (3) requests for assistance by KEPCO. KPS site manager attends KEPCO's daily staff meeting to discuss progress and problems of their work. KPS also holds in-house progress meetings. The frequency of meetings varies according to plant condition. Management's goals and policies for the plant are given to the contractor to be considered when contractor prepares a detailed implementation program. Team spirit between KEPCO and contractors has a strong emphasis on sharing common goals. Periodic checks are made to compare goals with accomplishments.

For the maintenance service companies, quality is the primary requirement. For that purpose, KPS develops QA plans with approval from KEPCO. According to the approved plans, KPS implements its own QA activities. KPS has its own QA training program. Wolsong requires the establishment of QA and training systems by bidders during negotiations. The requirement is applied when the manpower allocation is made. Training programs are classified into on-the-job training, contractor's in-house training, and external training. (See section KR.4.2.2.)

KR.4.1.5.2. Contractors during outages

During the scheduled outages, a number of skilled and trained technicians must be hired. KEPCO provides contractors with a planned outage duration schedule and work activities, and the contractors prepare the detail outage schedules, including the manpower resource allocations and submit the schedules to KEPCO for approval. KPS is in charge of mechanical and electrical maintenance during the periodic outages. The Wolsong management provides KPS with the basic work flow sheet. KPS derives the detailed work schedule, including personnel requirements. The amount of work varies each year. Samchang and Iljin schedules are the same as those applied during normal operation. Contractor employees during outages (there was no outage in 1993) were:

TABLE 5. CONTRACTOR EMPLOYEES DURING OUTAGES

	1990	1991	1992	1994	1995
Duration (in days)	45	31	53	62	59
KPS Mechanical	45	31	53	62	59
KPS Electrical	67	53	56	62	77
KPS QA	3	3	7	9	11
Samchang I&C	33	38	33	24	30
Iljin Protection	31	31	30	34	28
Iljin Treatment	5	9	9	9	9
Total	154	149	150	155	166

KR.4.1.6. Budget resources and allocation

KEPCO personnel are paid a salary from a budget approved by the government. The budget for contractors' employees is decided on a lump sum basis in negotiations between KEPCO and the contractors. Contracts are renewed every 3 years. Regarding other expenditures, a high priority is given to equipment replacement, spare parts, and the introduction of new facilities. Budget pressure on newly constructed power plants requires tighter control on expenditures of operating plants. Although there is minimum budget level required for maintaining plant reliability, each plant should have a budget higher than this minimum level. Also, in some years it might be necessary to invest several times the difference between the minimum budget and a higher one for a special modification. For example, in 1992 a large expenditure was made to improve Wolsong's computer reliability. This has helped enhance plant availability. The percentage of the budget devoted to various cost categories from 1990 to 1995 was

TABLE 6. BUDGET COST BY CATEGORY

Cost	1990	1991	1992	1993	1994	1995
Materials	43.9	36.0	32.1	35.6	25.0	23.0
Labor	17.7	20.5	20.1	20.5	17.1	18.3
Maintenance	23.0	25.1	27.5	25.7	33.7	34.7
Other	6.6	9.1	7.9	10.1	16.5	8.7
Capital	8.8	9.3	12.4	8.0	8.4	15.3

Also, the ratios of investment in modifications to the total budget were

TABLE 7. RATIO OF INVESTMENT

Year	1990	1991	1992	1993	1994	1995
Cost	9.3	9.7	12.7	10.0	9.0	15.9

(Note: In 1992 investment included the construction of the pressure tube maintenance centre and in 1995 investment included the purchase of pressure tube inspection equipment.)

KR.4.2. Personnel

KR.4.2.1. Personnel characteristics

Employees are educated in seven fields. Most of them studied in the mechanical and electrical fields. The percentages of employees in each of these fields are

- Mechanical engineering 31.0%
- Electrical and electronics 38.5%
- Nuclear engineering 12.0%
- Chemistry 6.5%
- Others (including physics) 12.0%

Most of the employees have university degrees (48.5%) or a junior college education (18.0%). The remainder graduated from high school.

The average length of job tenure at Wolsong is longer than at other nuclear power plants. Although senior operators and maintenance staff have considerably experience at Unit 1, many were reassigned recently for the construction and commissioning of Wolsong 2, 3, and 4. The average length of job tenure in Wolsong are presented in Table 8.

TABLE 8. AVERAGE LENGTH OF JOB TENURE

	Over 12 years	Over 3 years	Less than 3 years
Operator	42.7%	29.3%	28.0%
Maintenance staff	39.3%	32.6%	28.1%

When tasks require more education, they can be assigned to KEPRI (Korea Electric Power Research Institute) as a research and development project.

KR.4.2.2. Personnel development and training

The quality of training provided to staff is recognized as one of the most important factors in achieving good performance. Last year, the ratio of training investment to the plant budget was 0.3% at Wolsong. KEPCO has two different types of training: on-site training and off-site training. On-site training consists of classroom instruction at Wolsong's nuclear training center and on-the-job training in each department. Wolsong's nuclear training center performs training adapted to the PHWR site. The training centre has a high fidelity CANDU 600 full scope simulator. On-the-job training is accomplished by senior engineer or section chief using handout notes and training schedule adapted to each job site. Basic and retraining courses include:

- *Basic course:* New employees are taught plant specific thermal and nuclear courses after their basic training, practical training, on-the-job training, and site-specific training. There are 8 weeks of training, including site visits (20 hours).

- *Retraining program:* In case of operators, Wolsong nuclear training center uses the simulator and retrains operator in normal, abnormal, and emergency plant conditions. For maintenance staff, training includes PHWR plant fuel machine operation and maintenance, D_2O management, and plant computer operation.

For Management development, there are several areas such as leadership and team building, assignment of responsibility, decisionmaking, crisis management, QA management, and Seoul University management training.

Other courses for maintenance engineer, technical engineer, and special jobs are developed and implemented at the nuclear training center at the Kori site. There, new employees take the basic nuclear theory and system fundamentals courses. There are 24 courses for maintenance training, 10 courses for technical engineers, and 10 courses for special staff. Those courses are the main sources of producing licenses required by the regulator. The training courses for medium and high level staff are also available. They consist of 3 classes on management, policy development, and quality assurance.

KR.4.3. Working practices

KR.4.3.1. Plant status control

To maintain good plant control several practices have been implemented, including

- Twice a year, each shift operation team performs an on-shift emergency operation drill. On receiving the accident scenario, the team executes virtual mitigation actions according to emergency procedures. A plantwide simulation drill is also performed every other month.

  This drill is focused on checking the applicability of procedures.

- When turning over the plant to next shift, all the members of the next shift gather in the technical support center near the main control room for a briefing from the supervisor of the previous shift. After the briefing, each operator of the next shift takes over his duties in the location where the partner from the previous shift explains the status of equipment within his area of responsibility.

- Several itemized practices keep the plant from falling into a hazardous state. Equipment that could cause unnecessary reactor shutdowns as a result of natural events or grid disturbances is checked using a "Preventing Natural Events Procedure." Once a day, major safety parameters and changing trends are reviewed in detail.

- To avoid errors in the operation of critical equipment, the operation is conducted by more than one operator. The supervisor reads an instruction, the operator repeats the instruction, and each condition is identified by cross checking and verbal reporting. Once a week important parameters and their trends are reviewed in detail.

KR.4.3.2. Operations

The preparation, modification, and maintenance of procedures are strictly controlled. Notably, the associated managers in a meeting of the plant nuclear safety committee review safety-related procedures. The station manager must approve these procedure modifications. In several cases, such as when a new system is tested, a specific system or facility is not available during normal operation, or the existing procedures are not applicable, temporarily prepared procedures can be applied. Those procedures follow internal guidelines.

There are several operating aids at Wolsong. All the drawings for the operators are computerized and managed in the form of drawing image files. In the vicinity of major equipment, the related drawings are posted. A flow chart showing the activated annunciators and control status from the plant computer is available in the control room. Major valves that could cause operational hazards when inadvertently operated are armed with a locking system. In addition to the existing paging system for communications between operators, a new system has been developed that enables the receiver and caller to communicate immediately.

KR.4.3.3. Maintenance

Wolsong is operating well and preventive maintenance is being conducted in preparation for the aging of the facility. But in spite following maintenance procedures, 7 or 8 re-work items have been issued every year. To prevent human error from overhaul to overhaul (every 15 months) without trips or shutdowns, maintenance is guided by four policies: (1) intensive scrutiny of possible problem areas for 50 items, including PHT pump mechanical seals; (2) continuous use of procedure to prevent human error; (3) field checking done by each maintenance section daily, weekly, and monthly; and (4) natural disaster preparation and checking of facilities with seasonal problems.

Both intermediate and long term maintenance schedules for all systems and equipment is managed in a PC Database. On-line maintenance is prioritized in the database. However, items requiring shutdown are clearly stated in the outage schedule. Maintenance planning is being implemented on a per week basis at all times and on a per day basis during planned and unplanned outages. Call-ups consist of about 5 items, including rotating apparatus, vibration management, and 2,000 items managed by the plant host computer.

Regular maintenance jobs follow existing procedures. Irregular and special jobs are done after writing temporary procedures. Jobs on trip devices are witnessed thoroughly. Maintenance job management procedures include:

- work authorized after confirming procedures (temporary procedures)
- related section's technical review in case the work affects other plant systems
- work preparation reviewed, approved work plan issued, and "Order To Operate" created
- meeting before work
- meeting after work for main maintenance jobs.

KR.4.3.4. Technical support and other activities

Technical Support has been enhanced at Wolsong through the participation of international specialist teams and staff participation in international conferences:

- The IAEA OSART was held from July 24 to August 11 in 1989 at Wolsong.
- The 4th technical committee meeting on the exchange of operational safety experience of PHWRs was held from April 22 to 26 in 1996 at Kyongju.
- The WANO '97 peer review was held from March 10 to 22 this year at Wolsong.

KR.4.3.5. Interaction between work groups

Plant manager and deputy manager for operation visit the control room more than twice a day, in the morning (before the morning meeting) and in the afternoon, and they visit the supporting offices if required. Routine meetings in which all department managers participate are held daily, weekly, and monthly to discuss problems and adjust work schedules.

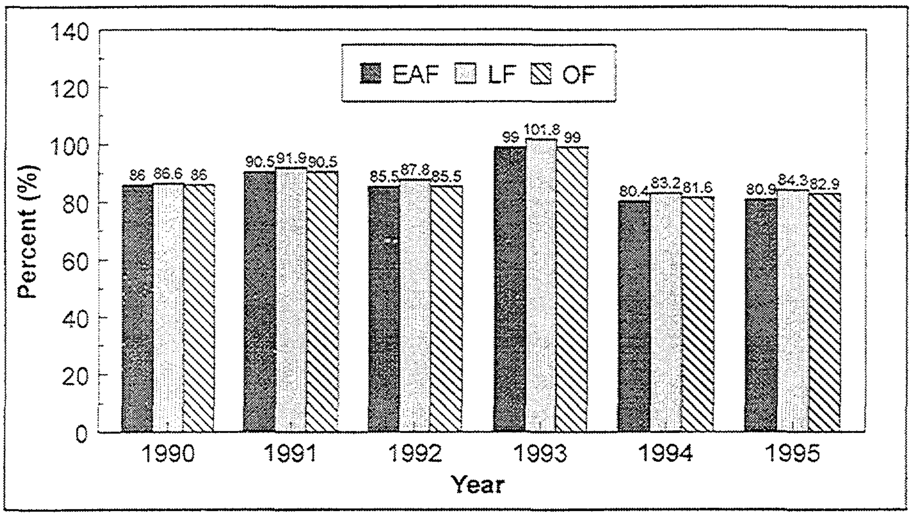


FIG. 1. Wolsong unit 1 performance data (PRIS) — energy availability factor/load factor/ operating factor.

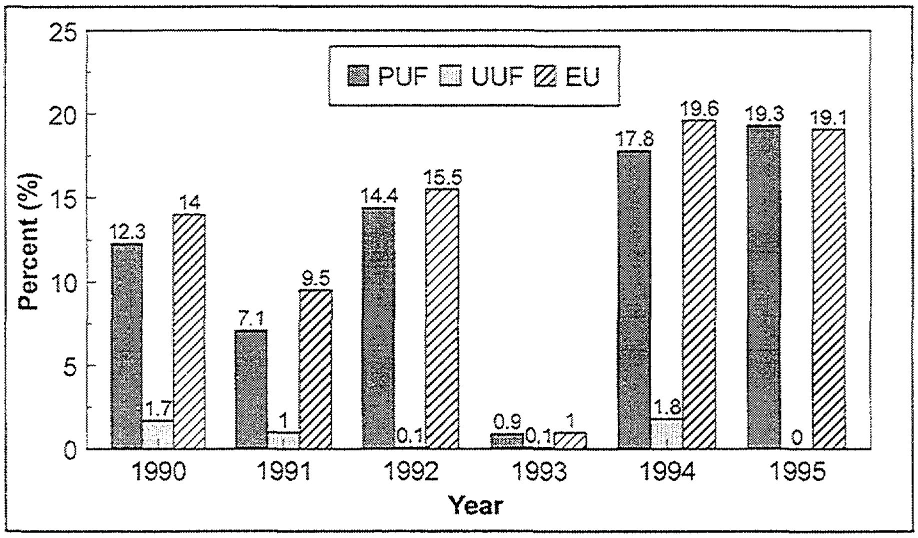


FIG. 2. Wolsong unit 1 performance data (PRIS) — PUF / UUF / EUF.

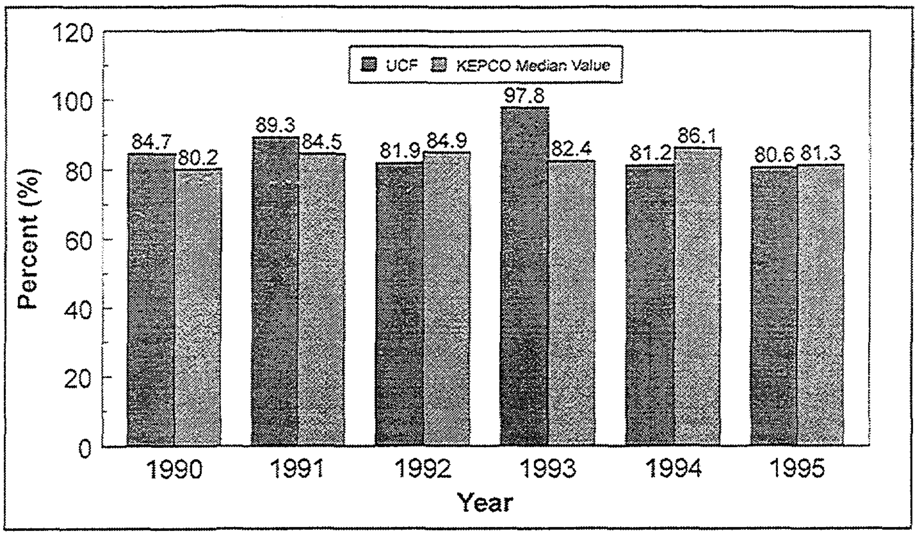


FIG. 3. Wolsong unit 1 performance data (WANO)— unit capability factor.

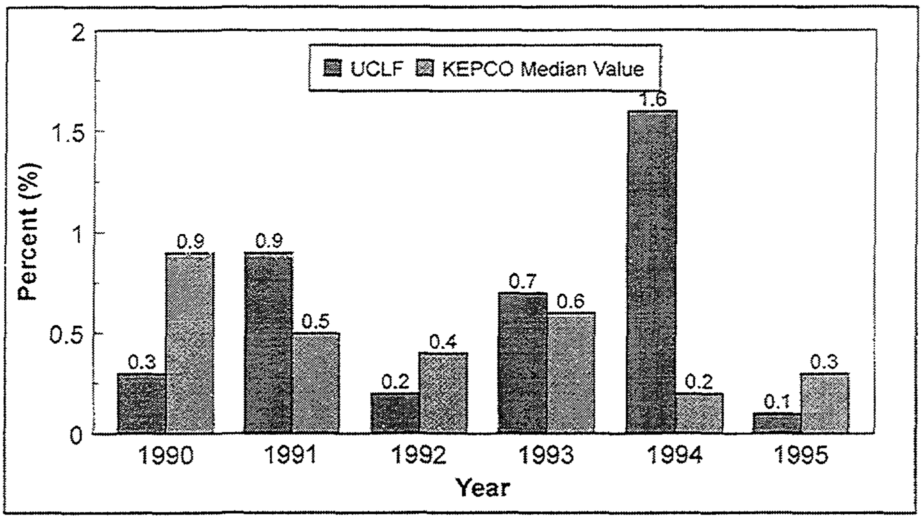


FIG. 4. Wolsong unit 1 performance data (WANO) — unplanned capability loss factor.

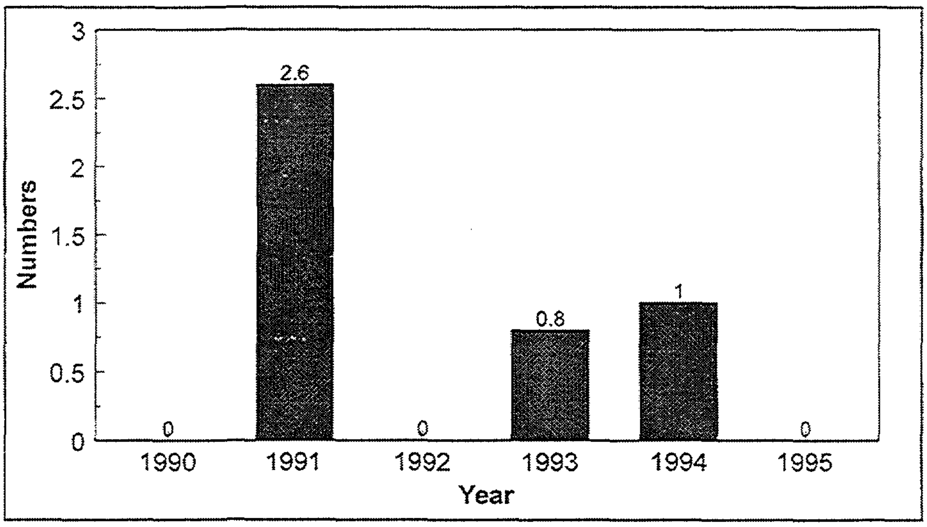


FIG. 5. Wolsong unit 1 performance data (WANO) — upsets per 7,000 critical hours.

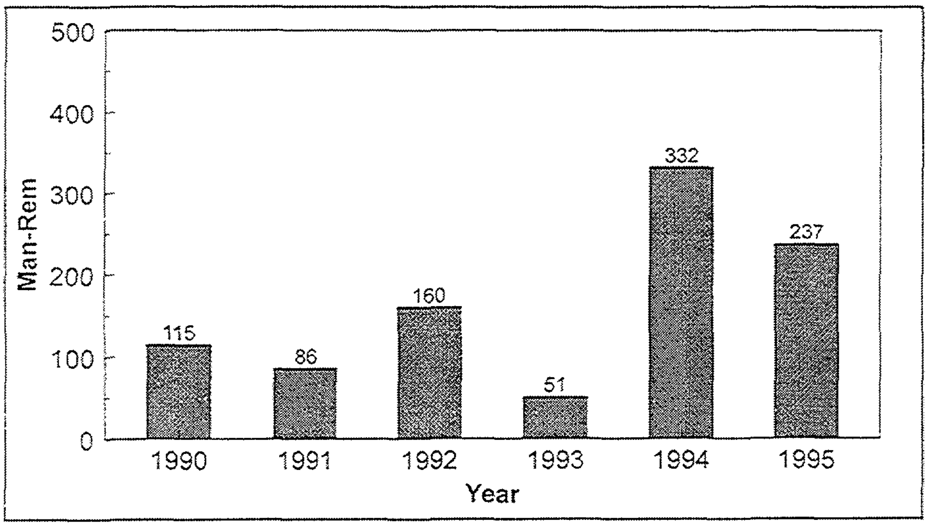


FIG. 6. Wolsong unit 1 performance data (WANO) — collective radiation exposure.-

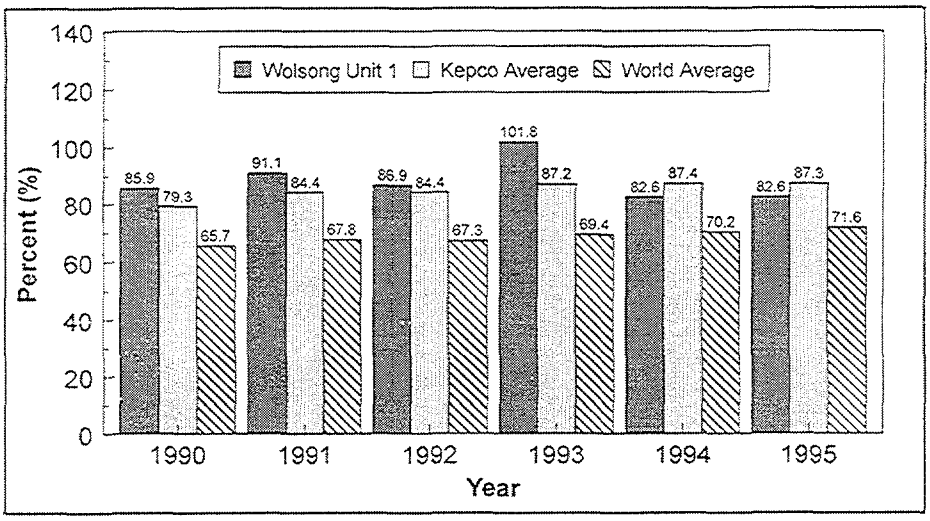


FIG. 7. Plant capacity factor.

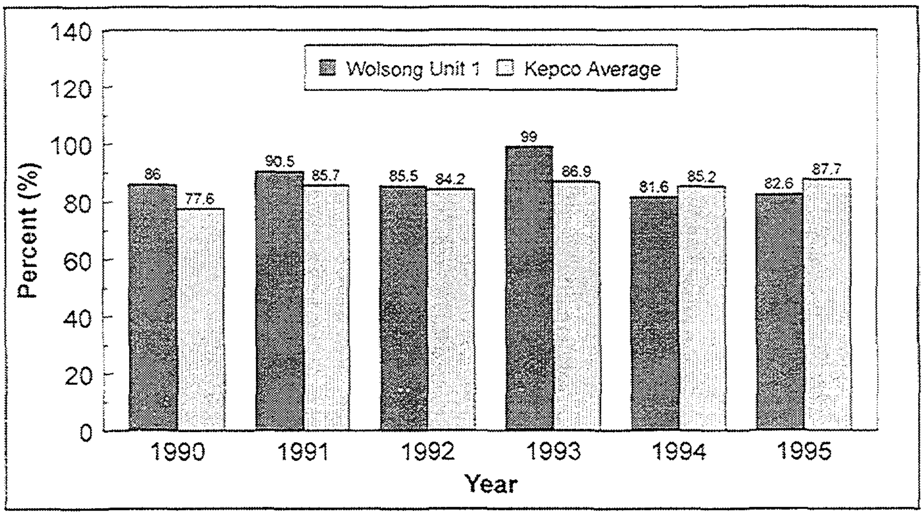


FIG. 8. Plant availability factor.

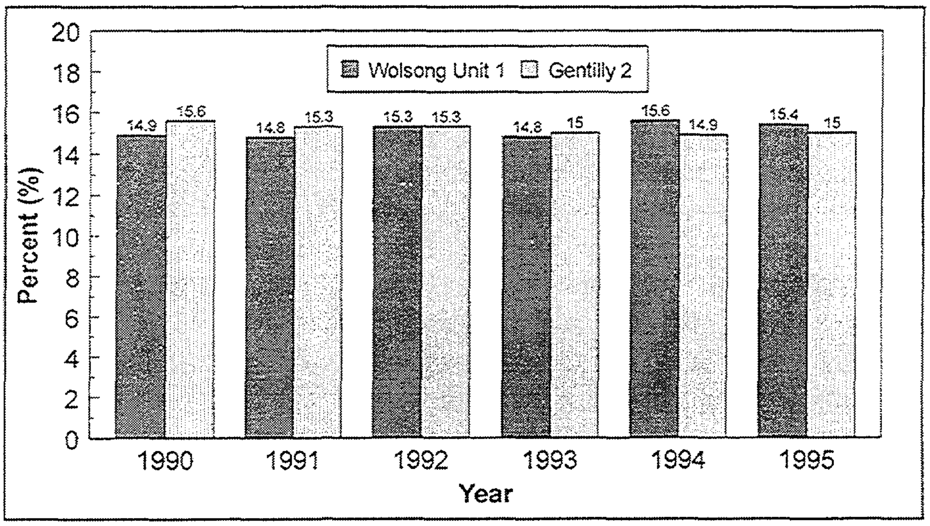


FIG. 9. Refuelling rate (BND/FPD) —comparison with gentilly 2 in canada.

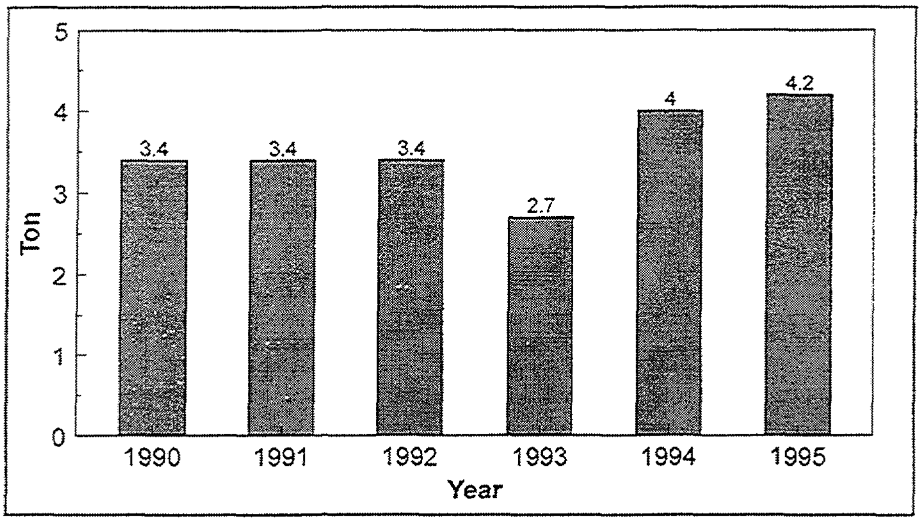


FIG. 10. D_2O loss/year.

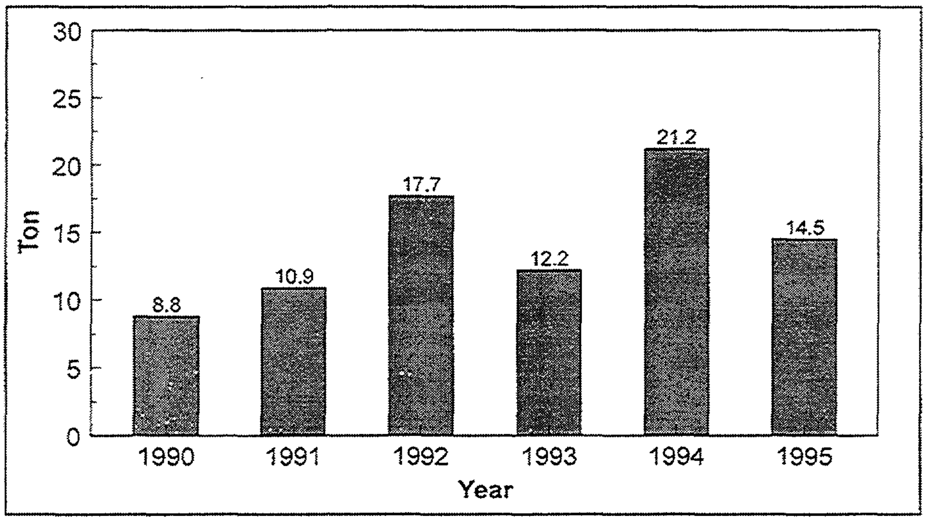


FIG. 11. D_2O recovery/year.

Annex F: TRILLO CASE STUDY

SP.1. PLANT DESCRIPTION

The Trillo I Nuclear Power Plant (Trillo) is located on the Tajo River in the municipal area of Trillo in the province of Guadalajara, Spain, at a distance of 93 km from Madrid. Trillo is owned by the electricity utilities Iberdrola (48%), Unión Eléctrica-Fenosa (34.5%), Hidroeléctrica del Cantábrico (15.5%), and Nuclenor (2%). Trillo is equipped with a three-loop PWR with a rated thermal power of 3010 MW. The reactor was designed by the German firm SIEMENS-KWU. It has 177 fuel elements. The plant has one high pressure turbine and three low pressure stages, the alternator with an output of 1066 MW(e) at 3,000 rpm. The condenser cooling circuit is equipped with two natural draught cooling towers. The most important milestones in construction of the plant were

TABLE 1. TRILLO NUCLEAR POWER PLANT (MAIN DATES)

Preliminary authorisation	04.09.1975
Construction permit	17.08.1979
Authorisation for test initiation	01.03.1986
Provisional operating permit	04.12.1987
Initial criticality	13.05.1988
Connection to the grid	23.05.1988
Commercial operation	06.08.1988

SP.2. HISTORICAL PERFORMANCE

The initial gross electrical output, following acceptance testing, was 1,010 MW(e). It maintained this level until 1991. In 1991 the power was increased by 56 MW(e) to its current level of 1,066 MW(e), following the replacement of the three turbine low pressure stages for others of a new design. The evolution of the main performance indicators was as follows.

TABLE 2. MAIN PERFORMANCE INDICATORS

PRIS Indicators	Average	1990	1991	1992	1993	1994	1995
Energy availability factor (EAF) percent	84.8	75.0	79.7	90.9	85.5	91.0	86.4
Planned unavailability factor (PUF) percent	13.0	16.9	19.3	7.7	12.0	8.8	13.5
Unplanned unavailability factor (UUF) percent	2.2	8.1	1.0	1.4	2.5	0.2	0.1
WANO Indicators	Average	1990	1991	1992	1993	1994	1995
Unplanned automatic scrams per 7000 hours critical	0.3	0.0	0.0	0.8	0.9	0.0	0.0
Collective radiation exposure (man-rem)	68.2	78.6	169.7	45.2	53.4	32.5	29.8
Volume of low level solid radioactive waste (m^3)	80.5	62.7	42.5	122.5	70.6	97.7	86.9
Other Indicators	Average	1990	1991	1992	1993	1994	1995
Gross production (GWh)	7763	6893	6939	8471	7888	8462	7976
Duration of refuelling outages (days)	43	50	61	27	43	31	48
O&M costs/gross production (Pta/ KW h, constant Pesetas as of 30.06.95)	1.36	1.58	1.53	1.27	1.33	1.19	1.24

SP.2.1. Discussion of the 1990–1995 period

The main circumstances that reduced the energy availability factor from 1990 and 1995 were

- Incorrect operation of the reactor coolant pumps (RCPs) led to two plant shutdowns in 1990, lasting 15 and 24 days.
- During the refuelling outage in 1991, the low pressure turbines were replaced and modifications were made to the RCPs.
- A 12-day outage in 1991 due to an ingress of sulphuric acid in the secondary circuit via the steam generator blowdown treatment system and an additional 7-day outage due to a leak in the boric acid additional system.
- In 1992, the turbine pedestal was raised to avoid vibrations at low load, and subsequently a card in the alternator voltage regulator failed, causing a 3-day shutdown.
- In 1993 the refuelling outage, initially scheduled for 29 days was extended to 43 days due to the detection of three cracks in the diffuser of one of the RCPs during an inspection, and subsequent repairs and full inspection of the other two pumps.
- The lengthy outage experienced in 1995 was conditioned by the operating experience and systems analysis program (AEOS). The AEOS program is a consequence of the discovery of design and construction deficiencies. It should be considered as an exercise in self-evaluation. It is carried out to check that safety systems comply with all design-imposed conditions and that their assembly has been consistent in all cases. This program detects documentation discrepancies and requires some physical discrepancies to be corrected.

SP.2.2. Performance indicators for the period before 1990

Only the last few months of 1988 and all of 1989 are outside the 1990–1995 period. PRIS performance indicators for 1989 were

TABLE 3. 1989 INDICATORS

Energy availability factor (EAF)%	83.7
Planned unavailability factor (PUF)%	15.2
Unplanned unavailability factor (UUF)%	1.1
Gross output (GWh)	7,643.0
Outage duration (days)	45.0

SP.3. OVERVIEW OF THE TRILLO CASE STUDY

Highlights in this case study include (1) following the resolution of the technical issues associated with the early years of operation, a corporate project was developed with the definition of the mission and the vision of the organization, described in section SP.4.1 and (2) some of the results achieved by the corporate project have been

- Organizational development plan (Section SP 4.1.1.)
- Strategic plan for 1995–2000 (Section SP 4.1.2.)
- Communications plan (Section SP 4.1.3.)

Other aspects of interest are (1) the implementation of a total quality management and on-going improvement programs; (2) changes in policy regarding relationships with contractors; (3) training evaluation methods; (4) activities associated with reduction of the number of shifts; and (5) maintenance optimisation plan.

SP.4. MANAGING AND WORKING AT TRILLO

SP.4.1. Management practices

Central Nuclear de Trillo I (Trillo) is a business group established in 1993 to manage the plant. Its mission is: "to provide service to the public by supplying electricity with safety and quality at competitive prices, increasing the quality of life and customer well-being"

Its objectives also include (1) promoting the human development of plant employees, (2) collaborating with the suppliers of products and services, and (3) protecting the environment. Its Vision is: "to be a technical and economic leader among european nuclear power plants"

Management is also oriented towards continuously increasing the level of aptitude and quality of the organization. With this aim in mind, a systematic methodology has been established to achieve (1) the participation and commitment of all personnel and their active integration; (2) team work at the very core of improvement; (3) process, activity, and task-based management; and (4) problem solving and on-going enhancement of day-to-day tasks as a means of ensuring compliance with strategic objectives. The basic philosophy was developed during the period 1993–1994 and is reflected in the corporate project. Because all personnel participated in establishing its principles, personnel are committed to its implementation. The corporate project includes a set of convictions, values, principles, policies, and strategic objectives. These serve as reference points for all activities at Trillo.

To facilitate an understanding of the corporate project, the simile of a tree is used. This tree springs from a ground of **convictions**. Its roots — **essential values** — constitute the basis for the organization's stable nature, mapping out behaviour patterns in management and operation of the business and in relationships between people and with the surroundings, facilitating a stimulating climate and acting as a vehicle for motivation allowing people to develop efficiently in their work. The trunk — **cultural principles** — grows from these essential values, serves as a guideline for decision making in corporate management, is highly stable, and is affected only by major changes to the environment. The branches — **policies, strategies, and plans** — (which are renewed periodically) are adjusted or modified to respond to natural changes in the environment. However, some large branches that grow directly from the trunk. These are based on the cultural principles and are stable. Finally, the fruits — **annual results** — spring from compliance with the corresponding yearly plans. Consequently, the corporate project rests on the following pillars:

Convictions

- The individual is the key input
- Respect for the environment
- The service is important for society
- Long term survival requires the ability to compete
- A job well done makes all the difference
- Suitable income should be paid to both the employees and owners of Trillo

Essential values

- Priority attention to safety
- Attention to, confidence in, respect for, and understanding of the individual
- A high degree of ethics and integrity
- Team spirit
- Emphasis on action with reflection
- Initiative, innovation, and professionalism
- Perseverance in efforts and the desire to improve
- Transparent and constructive self-criticism
- Participation and communication

SP.4.1.1. Organizational structure

The current organization was restructured in 1993 following the change in corporate trajectory, discussed above. The organizational structure of Trillo (shown in Attachment 1) is based on clearly defined lines of responsibility. These lines define a sharing of tasks and the accurate establishment of goals for each link in the organizational chain along the primary axes of safety, quality, competitiveness, and transparency. Trillo's structure is governed by a combined pursuit of (1) functionality, (2) horizontal configuration, (3) agility and flexibility, (4) quality service, and (5) optimised operating processes.

The management team, led by the manager and director, determines the strategies that guide the operating sub divisions. The manager and director are accountable to the assembly of partners, made up of the owner companies, and to the Board of Administrators, which includes two representatives from each owner company. The management team is responsible to implement the organizational development plan based on the following principles:

- Safe plant operation is the essential value of the organization; all divisions must create conditions to facilitate its achievement.
- Client-supplier relationships define interaction among the divisions of the organization. The primary client is operations. The suppliers to this client are human resources, economics-administration, technical, and quality assurance.
- There should be simplicity and clarity of structures through flexibility, a reduction in hierarchy, and a decentralisation of direct actions.
- The organization must focus on (1) the essential values and (2) on functions providing greatest value added.
- The organization must provide on-going learning and training.
- The proper mental approach is one oriented toward action and overall results.

SP.4.1.2. Strategy and Goals

Trillo has a 5-Year strategic plan. It provides a long term view of the organization in accordance with its business objectives. (See Attachment 2.) These objectives have been approved by employee representatives. A system of economic incentives based on compliance with annual objectives has been established. The strategic plan's objectives are:

- The implementation of the corporate project
- The implementation of general objectives including (1) policies regarding safety, improved operations, development of company projects, etc., and (2) results defined by load factor, duration of the refuelling outage, collective radiation dose, costs, etc.
- The implementation of detailed objectives of the action plans.

The strategic plan and action plans are revised annually, taking into account the results of internal input and off-site data through benchmarking. Action plans of the strategic plan are

(1) Organizational development plan
(2) Safety-related action plan
(3) On-going improvement plan
(4) Information systems and communication plan
(5) Facility technological maintenance plan
(6) Spares and suppliers management plan
(7) Production improvement plan
(8) Wastes and environmental plan
(9) Plan for relationships with the surroundings
(10) Documentary management plan
(11) Fuel-related action plan
(12) Plan for improvement of process and operational aid computing

SP.4.1.3. Management involvement and communication

The corporate project defines the basis of the communications plan. This basis is

– An open door policy with transparency and receptivity, allowing a climate of confidence, credibility, and support for Trillo's safety culture
– Pursuit of opinion with good listening and the availability of an evaluation system
– Analysis groups to aid the pursuit of efficiency through team work
– Channels for in-house expression so employees become the company's most important representatives
– External communication to ensure perceptions of the company coincide with intended image.

To implement the communications plan, the communications infrastructure includes (1) personal letters from the management; (2) publishing an in-house communications bulletin; (3) publishing the magazine Alcarria Alta; (4) general refuelling outage meetings; (5) miscellaneous informative meetings; (6) opinion polls; and (7) strategically distributed TV monitors with plant information (plant status, compliance with objectives, compliance with programs, etc.). These media, plus meetings with employee representatives, facilitate the transfer of information in both directions, and help to create a climate of understanding and commitment.

SP.4.1.4. Managing quality

Trillo has established a quality assurance program. Its objective is to ensure that plant operation is carried out in a reliable and safe manner, in accordance with the specified operational limits and conditions. The program currently in force has not undergone important changes in the last few years, its validity having been verified through the results obtained. The principles and objectives of the program are applied to all activities affecting the safety function of the structures, systems, components, and equipment. It covers the following areas: organization, plant operation, periodic and surveillance testing, maintenance, design modifications, nuclear fuel, reactor engineering and results, in-service inspection, chemistry, environmental radiological surveillance, fire protection, radiological protection, emergency plan, acquisition of equipment and services, security, stores, records management, personnel training and qualification, processing of operating experience, and computer applications.

Qualitative measures of the QA program include numbers of QA activities, audits, and the volume of documentation. The following table shows the main quality assurance activities in terms of audits, inspection point programs (IPPs), and preventive and corrective maintenance activities:

TABLE 4. QUALITY ASSURANCE ACTIVITIES

Activity	1991	1992	1993	1994	1995	1996
Audits	11	11	14	11	17	14
IPPs inspected	11	630	627	925	741	805
Preventive	653	734	311	483	492	321
Corrective	183	354	356	162	261	186

As part of the sector-level activities carried out with the quality assurance organizations of other Spanish nuclear power plants about 50 annual supplier audits are performed. There are currently about 150 favourable evaluated suppliers. The volume of documentation subject to the QA program for procedures is 1897; for operating manuals is 216; and for maintenance instructions is 1688.

With progress toward priority safety activities, the decision was made to address total quality management (TQM) and the maintenance of excellency within the organization through a strategic approach. The TQM began at the end of 1995 on the basis of the EFQM model. An initial self-evaluation was performed and 200 activities for improvement were identified, grouped into 10 projects. Once prioritized, these were immediately implemented. Nineteen people have received specific training and most personnel have attended general courses. A second self-evaluation has been scheduled for 1997. Most plant personnel will participate and receive specific training.

The following reference documents were used in creating the QA Program:

- SPANISH NUCLEAR SAFETY COUNCIL, Quality Assurance at Operating Nuclear Installations, Safety Guide No. 10.7/88, Spanish Nuclear Safety Council.
- SPANISH NUCLEAR SAFETY COUNCIL, Basic Quality Assurance Guide for Nuclear Installations, Safety Guide no. 10.1/88 (Rev. 1), Spanish Nuclear Safety Council.
- SPANISH STANDARDS ASSOCIATION, Quality Assurance at Nuclear Installations, UNE Standard 73-401-87, Spanish Standards Association.
- INTERNATIONAL ATOMIC ENERGY AGENCY, Code on the Safety of Nuclear Power Plants: Quality Assurance, Safety Series No. 50-C-QA (Rev. 1), IAEA, Vienna (1988).
- INTERNATIONAL ATOMIC ENERGY AGENCY, Establishing the Quality Assurance Programme for a Nuclear Power Plant Project: A Safety Guide, Safety Series No. 50-SG-QA1, IAEA, Vienna (1984).
- INTERNATIONAL ATOMIC ENERGY AGENCY, Quality Assurance During Commissioning and Operation of Nuclear Power Plants: A Safety Guide, Safety Series No. 50-SG-QA5 (Rev. 1), IAEA, Vienna, (1986).

SP.4.1.5. Relationships with contractors

Company principles with respect to the use of contractors are (1) performance of the maximum number of tasks by plant personnel; (2) promotion of job versatility among the plant personnel; and (3) dedication of plant personnel to tasks of maximum value added. During normal operation in 1997, contractor personnel integrated into the main operating groups of the plant were

TABLE 5. NUMBER OF CONTRACTOR PERSONNEL

Operating Group	Contractors
Operations	3
Production engineering	0
Chemistry	2
Mechanical maintenance	10
Electrical maintenance	8
I&C maintenance	18
OTM & stores	11
Radiation protection & fire-fighting	32
Total	84

The personnel contracted during refuelling outages vary depending on the scope of the work to be performed with a daily maximum of 914 and a daily average of 620. Outage personnel must already be trained; Trillo management is responsible only for training on Radiological Protection and the Emergency Plan. With a view to ensuring the maximum collaboration and performance of outage personnel, meetings are organised before the refuelling outage with contractor managers. During these meetings, the refuelling plan, the scope of work, and the main objectives are presented and debated. Contractor representatives are responsible to transmit all information to their personnel. After the outage an anonymous survey is also taken in which all outage personnel are requested to provide their impressions of the outage. Subjects of the survey include treatment received, material resources on hand, schedules, opinions regarding the dressing rooms, etc. The results of the survey are used as a basis for the introduction of improvements in the next refuelling outage.

SP.4.2. Personnel

SP.4.2.1. Personnel characteristics

The following table shows the evolution of the plant personnel, both on-site and at company headquarters, a distinction being made between employees and "permanent" contractor personnel:

TABLE 6. PLANT PERSONNEL

Personnel	1990	1991	1992	1993	1994	1995
In-house	415	414	411	402	396	392
Contractor	373	313	244	240	236	205

Approximately 40% of the in-house personnel are university graduates, the rest having specific professional licenses. In 1996 the academic qualifications of Trillo personnel were 51 senior engineers (5 to 6 years of university education), 91 engineers (3 years of university), and 243 skilled workers (with professional education certificates for the job held or study at the pre-university level).

Regarding personnel experience, all the management personnel have wide experience of the nuclear field and have participated in construction, erection, testing, and operations, far exceeding the experience established in current recommendations. Line management includes senior engineers or engineers working in operations and technical support. Generally, the operations personnel did not have experience in plant operation when they were hired. However, during their training phase (1983 and 1984), they made extended visits (more than eight months) to plants in the testing and operations phases in Spain and Germany. These employees participated in and had direct responsibility for the performance of work corresponding to the testing and start-up of Trillo. Technical support includes areas such as engineering, safety and licensing, fuel, and quality assurance. These personnel have extensive experience at Trillo due to their involvement from the beginnings of Trillo's construction.

Skilled workers are employed primarily in maintenance. The maintenance personnel were hired from among the staff of the contractor companies who have worked at Trillo, bringing with them the experience and skills required for this type of work. Further, in view of the fact that nuclear power plant specialities are not included in the Spanish education system, a decision was made to hire "younger" people with a high capacity for learning and with degrees appropriate to the posts to be filled. For some of the positions in the initial training program, extended visits were made to operating plants, including periods of specific operations, such as refuelling.

The stability of the Trillo work force is very high, and only a few people have left in the 8 years of plant operation. There is a clear policy of possible vacancies appearing within the organization being fed from below, such that a vacancy in the upper echelons of the organization opens expectations at lower levels. Also, at Trillo according to the corporate project, the criterion of accepting added value task performance promotes the "rotation" of the personnel from two perspectives: (1) to promote the polyvalency and an increase of personnel knowledge and (2) to enrich employment through the inclusion of new tasks and scopes of responsibility. By way of an example, the following courses were given during 1996 with one or both of these orientations:

- Functional versatility of auxiliary operating personnel
- Waste treatment monitors
- Functional versatility of control room operators
- Safety and hygiene monitors
- Load movements

SP.4.2.2. Personnel development and training

The annual budget for contracting off-site courses aimed at developing and preparing personnel has increased. In 1995 training represented 2.4% of the total Trillo budget and 6.2% of the average working day of Trillo personnel is devoted to training, increasing capabilities, and functional versatility. In 1995 a total 31288 man-hours were dedicated to training, distributed among 249 courses and 1937 trainees. The courses were divided into four major groups: (1) specialist courses, (2) mandatory courses (radiological protection, emergency plan, etc.), (3) licensed operator re-training, and (4) general courses. Since 1995, due to the impulse received as a result of the change in company culture initiated in 1993, the courses have been grouped as (1) corporate project, (2) strategic plan, or (3) routine. Until 1996, the management courses were delivered individually. However, in 1996 a process of generalised deployment began. This process is now expected to increase significantly. The initiation and development of the on-going *improvement plan will increase hours in training significantly.*

Evaluation of the effectiveness of the courses, which depends to a large extent on the quality of the instructor and the materials, along with the willingness of the trainee, is based on the following:

- **Reactions of the trainees**: This is a measure of the trainees' degree of satisfaction with the contents of the courses, methodology, environment, etc., on completion. It is accomplished using questionnaires that are delivered on completion of the activity, and serves to obtain average values for design, methodology, and the impact of the course on daily or future activity.
- **Learning skills**: This is a measure of the level of knowledge and skill acquired by the trainees, both individually and collectively. It is accomplished through tests and examination designed to determine knowledge and skill.
- **Transfer to the job**: This is a measure of the suitability of the content of the courses to the needs of the job. The corresponding transfer being evaluated in terms of the change in the on-the-job behaviour of the trainee after 3–4 months. This activity was initiated in 1996, but evaluation has been difficult.

Over all course evaluation done by individuals (students and supervisors) can be found in Attachment 3. The results of the evaluation are used to improve courses when they are repeated, and in planning the annual training programs. Finally, two training practices at Trillo should be highlighted.

1. Training materials for non-licensed operators: One of the objectives of operations management is to qualify non-licensed operators in more than one building or area. In-plant training materials were developed and organised, first by building/area and then by systems within the building/area. This type of organization is used by instructors and students and provides a logical path for self-study, training, and qualification. The training materials package includes (1) specific knowledge and skills, (2) learning objectives, (3) job-task description, (4) equipment layout drawings, and (5) important procedural steps for performing various system operational evaluations.

2. Simulator training logbooks: Simulator logbooks are kept by every reactor operator license holder. The simulator logbook is designed to have the student perform the following:

- record each scenario and its effects on the trainee's work station, including the actions taken by the trainee
- reflect on any lesson learned, including performance needs during each scenario
- identify new questions that resulted from the experience, as a reminder to discuss such issues during subsequent classroom or simulator training sessions

The management expects licensed personnel to record specific information in the logbooks during annual simulator training. This requirement has reinforced the importance of the individual's contribution to the learning process. Additionally, the expectation to reflect on the lesson learned from each scenario has resulted in quality feedback to the organization. The use of this book during simulator training has resulted in changes to procedures, revisions to the training program, and modifications to the simulator.

SP.4.2.3. Personnel behaviour and attitudes

At Trillo, many courses have been delivered to improve personnel behaviour and attitudes. Some of these courses have been (only those covering wide sectors of the organization) ASSET at Trillo NPP, 1991; HPES sector courses by UNESA/TECNATOM; human factors I and human factors II; self-checking; communications and self-checking; safety culture; team work; and fffficient meetings

SP.4.3. Working practices

SP.4.3.1. Plant status control

Plant status is monitored in the main control room with computer systems described below at SP.4.3.2.2 and through surveillance walk-throughs:

- Every 2 hours the control room personnel check panels for which they are responsible

- Every 4 hours the auxiliary operators walk through the buildings for which they are responsible (six auxiliary operators covering 100% of the plant buildings) and they carry out specific walk-throughs depending on plant needs

This information is included in seven logs (1 per building plus the control room log). The shift supervisor has a copy of these logs and immediate access to whatever information he considers relevant. On shift handover, a briefing is held to transmit the information and data in the logs, comment on events, and inform of the list of existing in-operabilities. To minimize alarms, corrective work is performed immediately by the operations personnel themselves, whenever possible. Only in case of the inability to clear an alarm would a work order be issued to the maintenance division. Temporary modifications are resolved and attempts are made to minimize them through periodic meetings to monitor their status.

SP.4.3.2. Operations

At Trillo the operations section is made up of the operations manager, the shift personnel, and the operations technical office. There are seven operating shifts. Each shift has a shift supervisor (licensed SRO), an assistant shift supervisor (licensed SRO), a reactor operator (licensed RO), a turbine operator, and six auxiliary operators. During the initial years of operation, the operations team was supported by personnel working in closed shifts from the three maintenance specialities (mechanical, electrical, and I&C), chemistry personnel, fire protection people, etc. Later, extra support personnel were not assigned to closed shifts (except for one fire protection technician). So, operations personnel were required to acquire new knowledge and skills and perform new functions, such as periodic greasing of equipment, correction of local leaks, fuse changes, periodic walk-throughs of fire protection systems, etc. This is known as "productive maintenance."

Another plant objective has been to reduce the number of shifts to six. This will require (1) Turbine operators to obtain a reactor operating license; (2) license-holding technicians to be available for procedural revisions, PSAs, etc.; and (3) auxiliary operators to attend "functional versatility" courses to train them in knowledge of the tasks associated with all the external buildings and areas of the plant. These courses will last 6 months.

SP.4.3.2.1. Operating procedures

Operating procedures can be divided into two types: administrative and technical. Technical procedures can be sub-divided as

- Shutdown 4
- Startup 3
- Failure 23
- Emergency 19
- Others 171

Safety-related procedures are revised every three years. Non-safety-related procedures are revised every five years. Emergency procedures are revised by the operations personnel and checked by the personnel of the main vendor. Apart from these periodic revisions, there is a "procedure alteration" format (shown in Attachment 4), which is used whenever errors are discovered in a procedure or a change is introduced. Until a new revision is performed, temporary modifications are indicated on a controlled copy of the corresponding document in the control room, highlighted in a coloured copy (yellow) different from that of the procedure itself (white). Compliance with the surveillance procedures required by the operating technical specifications, some 400 in number, is the responsibility of the operations section.

SP.4.3.2.2. Operating Aids

Control room personnel have access to these computerized systems:

- Process computer. This provides information on the status of alarms, signals, and analogue values (8,000 binary signals and 800 analogue signals).
- Criteria computer. This provides the logic diagrams for the functional groups and carries out part of the periodic tests.
- Reactor protection system (RPS) warning computer.
- Various computerized programs, such as tag-outs, jumpers, temporary modifications, simulations, etc.
- Local area network for corporate applications, for example, maintenance management, design modifications, documentation, email, etc.

Other operating aids include

- *Labelling.* An administrative procedure regulates all the labels included on the control room panels.
- *Documentation.* On all necessary equipment there is supporting information such as flow diagrams, equipment drawing, operating instructions, specific status warnings, etc.
- *Protective covers.* To prevent the manipulation of some control room buttons inadvertent manipulation is impossible by design, since two buttons must be actuated simultaneously (one acting as a permissive).

SP.4.3.3. Maintenance

Since plant startup, an integrated maintenance and stores management system has been available. It provides the reliability and agility required for both the performance of maintenance tasks and the management of spares and general planning of work in the plant. Before defining the maintenance philosophy and criteria applied at Trillo, note the following.

- This type of KWU-Siemens plant has abundant monitoring capability, so predictive maintenance is reduced.

- Given that the plant has four safeguard trains and a larger number of items of equipment than other types, safety-related equipment can be tagged out with the plant in operation.
- Grouping components of systems susceptible to intervention under a common tag-out allows resources to be optimised.

SP.4.3.3.1. Maintenance policy

Trillo's maintenance goal is to ensure that the equipment actuates and fulfils its design condition when required to operate. To this end, a preventive and predictive maintenance plan has been designed. This plan attempts to minimize corrective interventions and is complemented with in-service inspection and periodic testing. Important efforts have been made to provide maintenance personnel with suitable training and with a documentary support. Technical aspects not covered by the supplier are complemented or solved with the assistance of the equipment manufacturers' personnel. The maintenance organization is responsible (1) for defining the content and updating the spares required for the activities included in the preventive maintenance program and (2) for addressing the possible repairs following the detection of faults. Management of maintenance activities and maintaining inventories of components and spares are conducted through a centralised computer system. This system also documents component histories. Maintenance activity assessment methods are currently being established to improve the effectiveness of interventions and their planning.

SP.4.3.3.2. Corrective maintenance

Corrective maintenance activities are the repairs or modifications required to ensure correct operation. Any of the plant organizations can detect the need to perform such tasks. These needs are communicated through "work requests." The maintenance service attends to such demands through four sections: (1) mechanical maintenance, (2) electrical maintenance, (3) instrumentation and control, and (4) maintenance technical office. On detection of an anomaly, maintenance service schedules performance, considering

- Priority, determined by the team issuing the work request
- Availability of materials for performance
- Preventive maintenance program schedule
- Capacity to perform at the time of appearance
- Conditioning factors relating to operation
- Technical aspects of the repair

The resulting weekly maintenance schedule is used as a basis for task co-ordination with departments other than maintenance, e.g., operations, radiological protection, and safety. All the processes are documented through non-scheduled work orders, which after completion, become part of the repair history file. This file includes information on the work performed, materials consumed, documentation used and generated during the repairs, and involved maintenance and supervision personnel.

SP.4.3.3.3. Preventive maintenance

Preventive maintenance is applied to all active plant components plus those passive elements that require periodic cleaning. It includes all activities not relating specifically to maintenance that might have an influence on performance, including periodic testing or predictive tasks, such as monitoring vibrations. This type of maintenance also includes tasks accomplished by other groups who have decided to control their periodic activities in the same way as maintenance. Opinions are issued for all tasks concerning whether equipment can be "available" or "tagged-out." The aim is to minimize the number of interventions, optimise maintenance work, and minimize disturbances to plant operating conditions. In addition, one of the foundations in organising preventive maintenance has been historic information support. This documentation makes it possible to evaluate both the results of maintenance and the behaviour of the plant equipment.

All maintenance tasks are reflected in scheduled work orders, which are issued individually for each performing group. These orders are interrelated when simultaneous performance is required. Each of the tasks listed in the scheduled work orders is included in a document known as the maintenance instructions. These describe (1) the initial conditions required for work on the component, (2) the general precautions to be taken, (3) necessary tools and foreseen spares and data on frequency, (4) hours of work required, and (5) the plant operating mode in which the work should be carried out.

The entire preventive maintenance system is based on the maintenance instructions and procedures related to specific structures and equipment, regardless of the function performed in the plant. The work described in the procedures (such as assembly and disassembly, calibration, functional testing, etc.) is applicable to both preventive and corrective maintenance. To aid maintenance scheduling, an exhaustive inventory of the plant components available to different maintenance interventions has been drawn up. These components are grouped by manufacturer and model, nuclear class, etc. In addition, available spares are assigned to each component group.

SP.4.3.3.4. Preventive maintenance criteria

The primary objective of preventative maintenance is preventing equipment from malfunctioning by maintaining it in acceptable conditions of operation, taking into account that many items of equipment have parts that are subject to progressive degradation. To accomplish this objective, the following analysis is applied to equipment subject to maintenance:

- Analyse documentation provided by the manufacturer and determine the operating condition of the component.
- Define tasks to be performed.
- Review previous experience with these tasks.
- Select the frequency of performance and its plant operating mode.
- Develop the procedures required for performance.
- Prepare the supporting documentation with data allowing subsequent evaluation.

As a result of this analysis, a system has been developed that includes two types of interrelated tasks: (1) tasks of great frequency related to lubrication, cleaning, visual checks, filter changes, etc. and (2) tasks that are more far-reaching in nature and less frequent. These include changing component parts of known service life, functional testing to ensure operability, inspections recommended by the manufacturers, etc.

Instrumentation warrants additional comment. All instrument maintenance involves the joint calibration of the sensing element, signal transmitter, and the indicating elements. There are also checks of the correct signal distribution to the main transmitters and checks of the setpoints corresponding to the limit values. This same approach has been adopted for regulation loops.

SP.4.3.3.5. Maintenance indicators

To aid those responsible for the Maintenance Division in evaluating maintenance progress, a set of indicators has been developed. These indicators include:

(1) Number of work requests

(2) Ratio between the number of activities and the number of work orders: This ratio can be calculated for type of work, degree of performance, responsible section, plant system, or date of performance.

(3) Ratio between man-hours worked and work orders: This ratio can be calculated for section involved, type of work, or category of the personnel.

(4) Ratio between preventive maintenance and total maintenance: This represents the ratio between Preventive Maintenance and the sum of Preventive and Corrective Maintenance over a unit of time. The ratio, expressed in percentage terms, is calculated based on man-hours. The effectiveness of the preventive maintenance is identified by comparing the number of man-hours of preventive maintenance and the number of interventions (per item of equipment or system).

(5) Corrective maintenance pending for more than three months: Corrective Maintenance is defined as the repair and restoration of equipment that has failed or did not function properly; not included are the Design Modification tasks that might be associated with solving a problem.

(6) Pending preventive maintenance: This is the percentage of activities, measured in numbers of Work Orders that were not performed within their scheduled period. A distinction is made between the preventive maintenance issued for performance (whose deviation has exceeded 25% of the desired interval) and maintenance, which (not having been issued for performance for reasons such as work capacity, availability of spares, operating conditions, etc.) has exceeded this time.

(7) Number of repetitions of work on the same component or system.

(8) Number of repeated inoperabilities of components or systems.

SP.4.3.3.6. Future maintenance strategy

Although Trillo's maintenance strategy has been effective, as can be seen in Attachment 5, the strategic plan includes technological maintenance as an objective of the action plans. The objective is to increase the efficiency of the maintenance while minimising costs. Two strategies have been chosen and are currently being implemented:

- Simplification of maintenance management (for minor maintenance activities and productive maintenance).
- Optimise maintenance by introducing reliability centred maintenance (RCM), a condition-based maintenance plan, and conducting specific studies of systems, components, etc.

SP.4.3.3.7. Outage activities

The duration of the refuelling outage has a direct influence on the plant performance indicators. The reduction of refuelling outage duration has been accomplished through (1) preparing a demanding, but doable, refuelling schedule and (2) controlling the following factors that influence compliance:

- Planning with sufficient time prior to shutdown.
- Continuous tracking of evolution of the program by the planning group and the rest of the organization responsible for management.
- Commitment by the personnel responsible for performance during the previous planning phase.
- Understanding among contractors of the overall program, its activities, and interconnections, and the organization of preliminary meetings with them.

The attached table shows the percentage evolution of refuelling activities.

TABLE 7. REFUELLING ACTIVITIES (%)

Type of Work (%)	1990	1991	1992	1993	1994	1995
Preventive maintenance	27	21	28	26	31	28
Corrective maintenance	35	37	28	30	27	16
Startup/shutdown activities	15	16	16	11	13	11
Periodic testing	4	4	6	7	7	6
Modifications	7	8	5	10	6	18
Cleaning and miscellaneous	12	14	17	16	16	21

SP.4.3.4. Technical support and other activities

As indicated SP.4.1.1, all the organizations at Trillo are at the service of operations, the main client. Consequently, radiological protection, health and safety, systems engineering, engineering, and operations, technical services, etc., centre their efforts on service to operations. These services are provided in the following ways.

Radiological protection. Apart from the periodic measurement performed by the personnel, following permanent monitoring is carried out from the control room: (1) radiation levels in 20 cubicles; (2) detection of contamination in the controlled zone; (3) activity released through the stack; and (4) contamination detectors in different systems equipped with heat exchangers associated with contaminated systems.

Health and safety. Three people are deployed during power operation. They attend the planning and task launch meetings. There is selected attendance and support for those whose presence is considered necessary.

Systems engineering is responsible for evaluating in-house and industry operating experience and for overall tracking of the plant systems. This group is responsible for root cause analysis. It performs analyses using the HPES and other methodologies.

Engineering supports plant operations and maintenance, designing all modifications and new projects and updating plant documentation.

Operations technical services was created in 1996 with the idea of having a unit disassociated from daily operations and maintenance tasks and in a position to take a medium and long term view. This service's work is to support operations and maintenance in the following areas:

- Management of the life of the installation
- Maintenance rule
- Maintenance optimisation
- Reduction of refuelling times
- Power increases
- Different studies to provide support to plant operations and maintenance

In addition, the Spanish regulatory body (CSN) has two inspectors permanently on site, so inspections are continuous. In addition to the above, the CSN carries out about 25 inspections annually (2 of which are non-scheduled) and another 27 yearly meetings to solve different problems.

SP.4.3.5. Interaction between work groups

The supplier-client relationship established by the organization can be summarized as shown in the following figure:

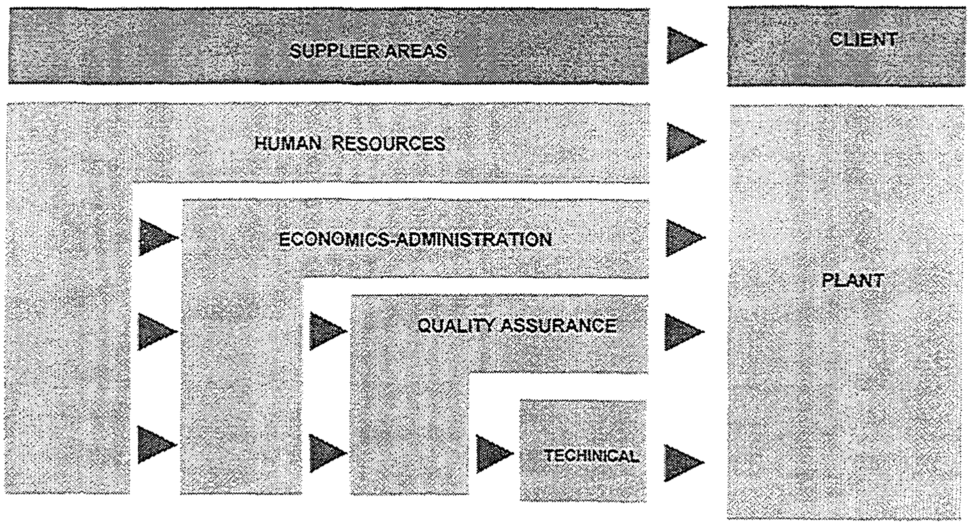


FIG. 1. Supplier-client relationship.

Basic communications between the different organizations are accomplished at the meeting of the management committee, which is attended weekly by the manager, director, and line managers. The matters dealt with and discussed at this meeting range from strategic and objective-related issues to specifically technical questions. Each sub-division also organises a weekly meeting to ensure communication in both directions.

At the operations level, a daily meeting is held in the control room, attended by representatives of operations, chemistry, maintenance (one representative from each maintenance section), quality assurance, systems engineering, health and safety, radiological protection, and the plant manager. At this meeting the plant status is analysed and urgent tasks are prioritised and scheduled. Planning of meetings involving people from various divisions is accomplished using a computer program — corporate agenda — running on an internal network (LAN and WAN). Also, email is available for all types of communications between people and organizations.

During refuelling outages communications are accomplished by way of a daily meeting attended by engineering, maintenance (1 representative from each section), operations, chemistry, radiological protection, health and safety, stores, quality assurance, etc. This meeting lasts approximately an hour and includes both tracking of critical activities and response to problems arising during the day. In addition, operations and maintenance hold a daily meeting to track the tag-out clearance program.

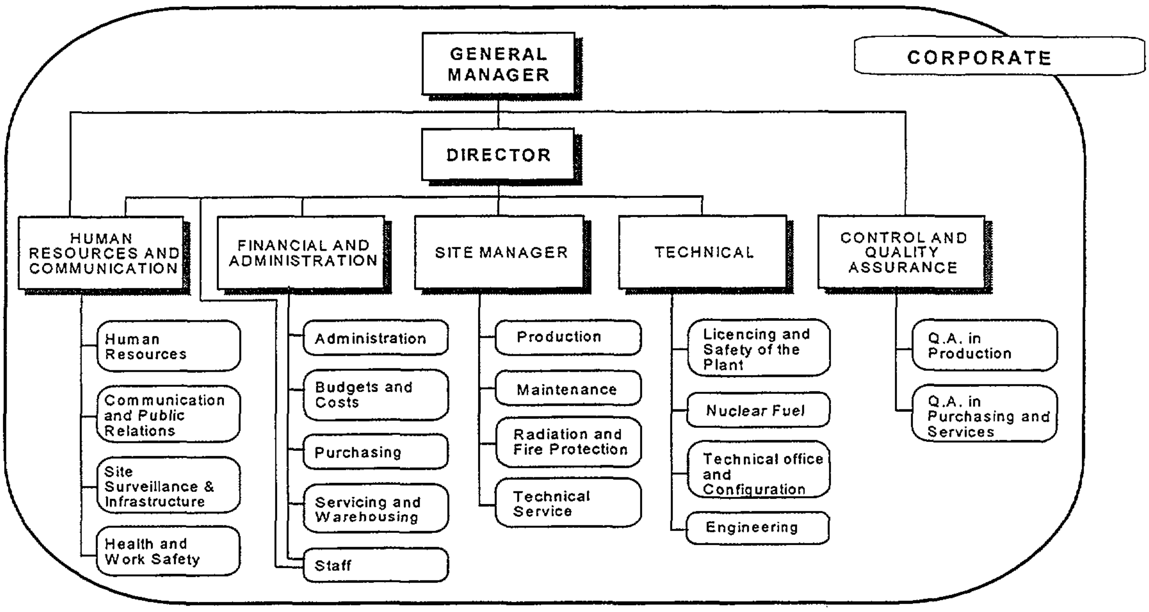


FIG. 2.. Organization chart.

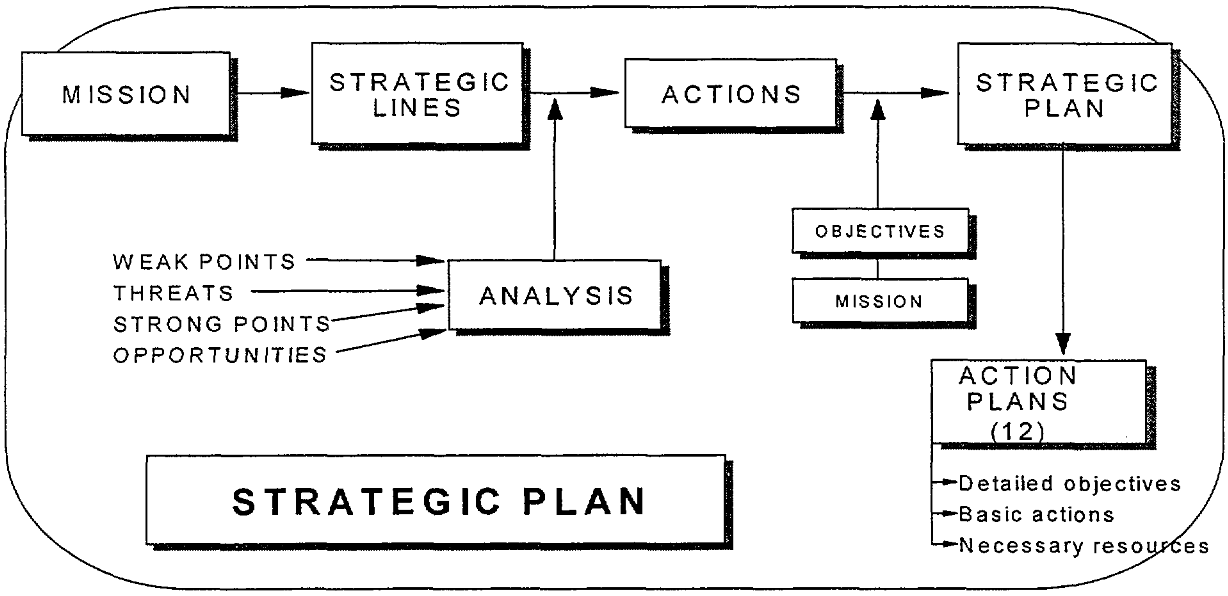


FIG. 3. Trillo 1 strategic plan.

EVALUACIÓN DEL CURSO

MONITOR TRATAMIENTO DE RESIDUOS

EVALUACIÓN DE LOS ALUMNOS

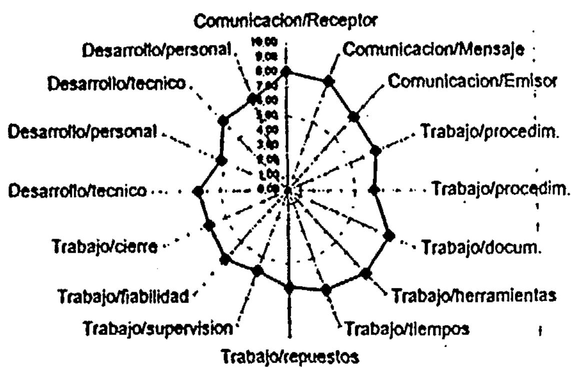
DISEÑO:	7,00	APLICABILIDAD:	7,50	METODOLOGÍA:	7,50

APRENDIZAJE

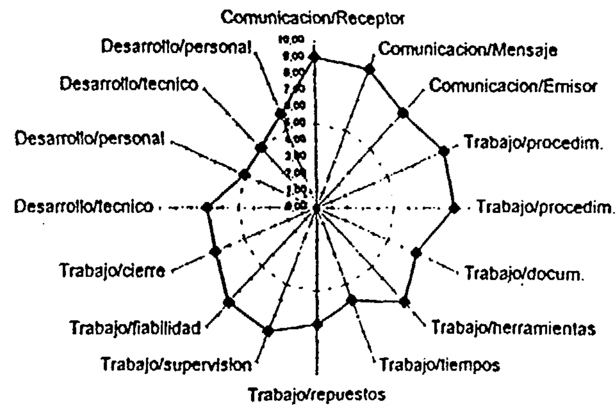
NOTA MEDIA:	9,10	SUSPENSOS:	1/15 .(MIN 80%)

TRANSFERENCIA AL PUESTO

DATOS ALUMNOS



DATOS SUPERVISOR



ALUMNO	COMUNICACIÓN	7,67	SUPERVISOR	COMUNICACIÓN	8,67
	TRABAJO	6,92		TRABAJO	7,50
	DESARROLLO	6,33		DESARROLLO	5,75

VALORACIÓN GLOBAL

IDENTIFICADOS PROBLEMAS EN LA DOCUMENTACION UTILIZADA EN EL CURSO. // LAS PRACTICAS FUERON SIMULADAS POR LO QUE SE PERDIÓ EFECTIVIDAD// EL PERSONAL YA ESTA DESEMPEÑANDO EL PUESTO POR LO QUE SE HAN CUBIERTO LOS OBJETIVOS PREVISTOS
EL CURSO DADAS SUS CARACTERISTICAS SE PUEDE CALIFICAR COMO : MUY BUENO

FIG. 4. Course evaluation

ALTERACION A PROCEDIMIENTO | HOJA DE

PROCEDIMIENTO Nº : REV.: FECHA :

TITULO :

SUBDIRECCION/UNIDAD EMISORA :

DESCRIPCION DE LA ALTERACION :

☐ VER HOJAS SUCESIVAS

RAZON DE LA ALTERACION :

☐ VER HOJAS SUCESIVAS

SE REQUIERE UN CAMBIO PERMANENTE EN EL PROCEDIMIENTO ☐ SI ☐ NO

SOLICITANTE	APROB. J. UNIDAD	CONFORMADO GARANTIA DE CALIDAD	NOTA : EL CAMBIO SERA REVISADO POR EL C.S.N.C. Y APROBADO POR EL SUBDIRECTOR DE EXPLOTACION EN UN PLAZO DE 30 DIAS DESPUES DE SU IMPLANTACION
INICIALES	INICIALES	INICIALES	
FIRMA	FIRMA	FIRMA	
FECHA	FECHA	FECHA	

APROBADO JEFE DE TURNO (*)	REVISADO C.S.N.C.	APROBADO SUBDIRECTOR EXPLOTACION
INICIALES FIRMA FECHA	SELLO	FIRMA
(*) SOLAMENTE SI EL PROCEDIMIENTO ESTA RELACIONADO CON LA OPERACION DE LA CENTRAL O LA ACTUACION DEL PERSONAL DE OPERACION		FECHA

RECOMENDACIONES Y OBSERVACIONES :

☐ VER HOJAS SUCESIVAS

FIG. 5. Procedure alteration form

TRILLO NPP

Planned energy availability factor (PUF) vs Unplanned energy unavailability factor (UUF)

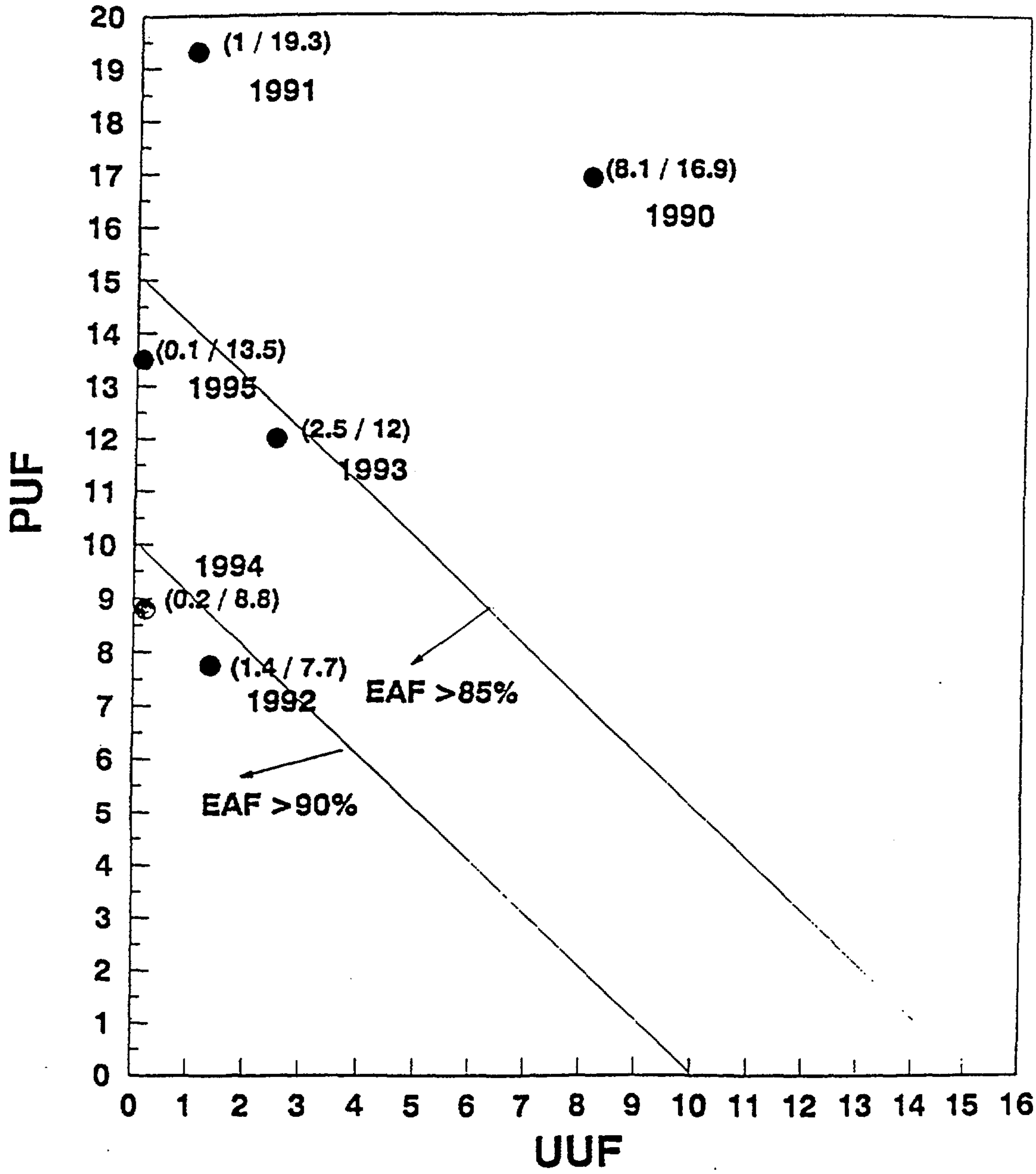


FIG. 6: PUF vs UUF

Annex G: LIMERICK CASE STUDY

US.1. PLANT DESCRIPTION

Limerick Generating Station (Limerick) is a two-unit boiling water reactor (BWR) located 34 km northwest of Philadelphia with a capacity of 1110 MW(e) (Megawatts-electric) per unit. Limerick Unit 1 went into commercial operation in February 1986 and Unit 2 in January 1990. Units 1 and 2 represent 25 percent of PECO Energy's generating capacity and typically account for more than one third (often as much as 44 percent) of the company's electric production. Limerick generating station is in the Nuclear Regulatory Commission (NRC) Region 1. Both units have a rated thermal power and licensed thermal power of 3,293 Mwt (Megawatts-thermal).

PECO Nuclear is a unit of PECO Energy Company, founded in 1881 and incorporated in 1929 as an investor-owned operating utility. PECO Energy has more than 195,000 stockholders and provides electric and gas services to a 5500 km^2 area with a population of 3.7 million in Philadelphia, Pennsylvania, and its surrounding suburban counties. It operates nine generating stations, owns a portion of three additional major plants, and maintains nearly 540 electric substations, 20,300 km of aerial lines, and 33,500 km of underground cable. PECO Energy operates in the Pennsylvania, New Jersey, Maryland (PJM) Control Area. See Attachment H.

The architect-engineer and constructor was the Bechtel Power Corporation. The Nuclear Steam Supply System and turbine-generator vendor was the General Electric Company. The two units are type BWR 4 with Mark II containments. The condenser cooling method is closed cycle with natural draft cooling towers. The condenser cooling water sources are the Schuylkill and Delaware rivers.

US.2. HISTORICAL PERFORMANCE

As part of PECO Energy's quality management philosophy, managing by fact is the norm at Limerick and throughout PECO Nuclear. One of the primary methods Limerick uses to accomplish this is through the use of performance indicators. Management identifies key process controls and then develops performance indicators to track their status. The performance indicators identify process goals and provide information about the level of world class performance for the process being measured.

Each work team identifies the performance indicators that are required to measure and evaluate their performance. These indicators supplement the standard INPO performance indicators. This information is critical to the work group supervisor and the directors, who report to the Limerick vice president. The indicators provide a detailed picture of the performance of each work team. They typically show 18 months of data and, if appropriate, running 12 or 24-month trends.

From these performance indicators a more focused, critical selection of performance indicators are reviewed monthly by the station management team and presented to the Limerick vice president and the president of PECO Nuclear. These indicators are presented by operational objective topic area and provide the management team the overall plant performance. For the most part, these indicators monitor the critical safety, cost, and performance aspects of Limerick. There are approximately 70 performance indicators for each unit. Several indicators provide station-wide information. All INPO performance indicators are incorporated in this group.

A reduced set of performance indicators are then provided to senior PECO Energy management and the PECO Energy Nuclear Committee of the Board of Directors. This is organized by operational objective and includes all the INPO performance indicators. It also includes the most critical performance indicators that provide insights into the health of the organization and the leading indicators that would signal degradation in performance. This summary includes approximately 25 indicators for each unit with a few common station indicators. They are the highest level indicators focused on the station's safety and economic performance.

PECO Nuclear issues a summary performance indicator compilation. This integrates the performance of Limerick, Peach Bottom, and Salem (a plant co-owned by PECO Energy, but operated by Public Service Electric and Gas). This compilation also provides a status of the PECO Nuclear Strategic Goals. See Attachment B for copies of the four performance indicator packages for 1995.

For a quick comparison of plant performance, PECO has developed a summary sheet that compares performance from year to year. It identifies long term trends and relates current year budget expectations to actual performance. This spreadsheet looks at production, cost, employees, and selected safety information. A copy of the 1996 comparison is provided as Attachment C.

Senior management has recognized that changes in behaviour and performance were needed to ensure that Limerick remained cost competitive. Several strategies were initiated to change organizational performance. They included switching from an 18 to a 24-month fuel cycle, refuelling outage length reduction, and an organizational re-engineering with a new work management system and a plant information management system. These changes have allowed Limerick to maintain its safety focus while reducing costs.

US.3. OVERVIEW OF THE LIMERICK CASE STUDY

Limerick's vision statement is "To be the best in the nuclear business." It is attempting to meet this goal by involving all managers and employees in creating a business plan that reflects its core values: safety, integrity, customer focus, teamwork, openness, trust, and respect, accountability, continuous learning, and embraces change. One of the key core values described in detail in this case study is "continuous learning." While all employees assume primary responsibility for personal development and career growth, management takes an active role in personnel development and training. Limerick's cross-training of managers and employees has enabled a reduction in the numbers of both permanent plant employees and contractors. Facing deregulation in electricity generation in the US, these personnel reductions have decreased O&M costs and made Limerick more competitive.

US.4. MANAGING AND WORKING AT LIMERICK

US.4.1. Management practices

PECO Nuclear has established a clear strategy and has communicated that strategy to the entire organization. PECO Nuclear's overall strategy is incorporated into the organization's vision and mission. Its vision is "to be the best in the nuclear business".

Its mission is "safely operate our nuclear plants, maximize our competitive position, and expand through profitable business opportunities."

To support the vision and mission, PECO has developed a set of values for all employees to achieve. The core values and behaviours provide the foundation for communications. These values are:

- Safety
- Integrity
- Customer focus
- Teamwork
- Openness, trust, and respect
- Accountability
- Continuous learning
- Embraces change.

These core values are consistently reinforced and are a part of each manager, supervisor, and employee performance appraisal. The following sections describe how the PECO vision, mission, and core values have been implemented at Limerick.

US.4.1.1. Organizational structure

The Limerick vice president provides leadership at the site. He has direct responsibility for establishing and implementing plant objectives. He reports to the president and chief nuclear officer and senior vice president located at the nuclear headquarters in Wayne, Pennsylvania. The plant organization also receives support services from the station support department also located at the headquarters facility. The on-site organization is structured along the lines of the major processes:

- The plant division is responsible for plant operations, radiation protection, chemistry, radioactive waste management, and experience assessment.
- The maintenance division is responsible for equipment repair, performance of predictive and preventive maintenance, surveillance, and work planning.
- The site engineering division, relying on system managers, is responsible for equipment performance and reliability, configuration management, and the design of modifications.
- The outage management division is responsible for scheduling outages, the work management system, contractor performance, project management, and materials management.
- The training division is responsible for the development, delivery, and evaluation of technical training for the station. The national academy for nuclear training accredits the training programs that operate under INPO.
- The site support division is responsible for industrial risk management, facilities management, business services, document services, security, emergency preparedness, and communications.

Within each division are a limited of number management levels (3 or 4) with a strong emphasis on the first-line supervisor. (See Attachment A.) Each supervisory position is filled through an assessment center that evaluates key behaviours, such as time management and work setting standards. After selection, each supervisor receives up to 8 weeks of training in the management and leadership skills necessary to supplement technical competencies. Two organization charts showing the overall structure of PECO Nuclear and an overview of the Limerick generating station organization can be found in Attachment A. The total staffing levels declined from 1992 to 1995:

TABLE 1. TOTAL STAFFING LEVELS

	PECO	Contractors	Total	MW h/employee
1992	1446	248	1694	8683
1993	1320	138	1458	11113
1994	1266	116	1382	11880
1995	1039	105	1144	13836

Between 1990–1995 the Limerick and PECO Nuclear organization was continuously improved with two key organizational interventions. In 1992 PECO Nuclear's executive team sponsored a study with the goal of improving the organization's operations. Following the recommendations of the Nuclear Effectiveness and Efficiency Design Study (NEEDS), the organizations was restructured. The objective was to create an organization that allowed the stations to focus on their efficient operation and have a support staff that worked on long term efforts and common programs. The reorganization has enabled the plant personnel to focus on plant safety and operation. Both PECO Nuclear stations use this centralized support organization. The NEEDS study was performed by nine key organizational leaders and was conducted in three phases:

- Data gathering and issue identification
- Analysis and conclusion
- Final recommendations on how to implement

PECO Nuclear senior management assigned line managers to work with the NEEDS team to finalize recommendations and to establish staffing levels and implementation steps. The line organization's responsibility ("ownership") of the outcomes made it successful. The NEEDS reorganization allowed a 15 percent reduction in Limerick staffing and a 30 percent reduction in the offsite support organization by reducing levels of management, combining fragmented functions, and aligning the offsite organization.

The second intervention was an early retirement program in 1994–1995. Based on changing management practices and the ability of the organization to change, there was a significant reduction in staff. As staff was effectively reduced, the performance of the plant improved. INPO performance indicators, O&M costs, and plant output all improved

Several key organizational tools support operational excellence at PECO Nuclear. First, a Hierarchy of Documents sets policies and directives and links them to the common procedure structure used for all PECO Nuclear units (Attachment D). This structure provides direction and promotes best practice development across sites.

A major success of PECO Nuclear has been enhanced Work Management Processes. This process has allowed PECO Nuclear, in conjunction with other management systems, to reduce annual outage times from greater than 100 days to approximately 25 days.

Limerick's Work Management Processes plans, schedules, and executes work. For outages, the key milestones, such as modification design and material procurement, are completed up to 6 months in advance of the outage. Routine work is planned and scheduled 10 weeks in advance. All group activities (for example, Engineering, Health Physics, and Operations) that contribute to the work management process can be found in the monthly performance report. Process improvements can be tracked to productivity improvements in performance of daily and outage work.

US.4.1.2. Strategy and goals

From the vision and mission, PECO Nuclear establishes both operational and strategic objectives. Operational objectives provide explicit direction where the organization is headed. strategic objectives are those used to bring about major change that move the organization towards its vision over the 3–5 year time frame. Throughout the early 1990's PECO Nuclear had six operational objectives and six to ten strategic objectives.

The vision, mission, values, operational objectives, and strategic objectives are incorporated into the PECO Nuclear poster, which is provided to each employee (Attachment E). This poster contains the overall direction of PECO Nuclear and is the basis for managements' discussions with their teams at the beginning of each year.

The business planning process for any year starts more than a full calendar year in advance. The PECO Nuclear executive team begins the process with an executive retreat. At the retreat, the mission, vision, values, and operational objectives are reviewed and adjustments are made. Changes to these are made when business conditions require. For example, because the vision established in 1988 was achieved, the present vision was introduced in 1995. The executive team reviews the strategies, determines those that have been achieved, and establishes additional strategies where major changes are needed. After the retreat this information is provided in a draft form for use in creating business plans.

Each cost center manager creates a business plan. These plans identify each division's goals and provide the linkage required to ensure that all goals are supporting the PECO Nuclear mission. The plans are developed with input from the employees obtained during situational assessments conducted during the second quarter of the planning year. From this meeting, the organization develops its goals including "stretch" goals. Stretch goals provide a step change in the division's performance. The business plans help ensure the horizontal linkages between divisions are obtained and identify the budget required. The business plan then provides each organization its overall objectives for the coming year.

The Limerick organization establishes its overall goals from the business plans generated by its cost centers. These overall goals are then incorporated into a poster that is shared with the all Limerick employees and support organizations. The poster identifies Limerick's mission and the goals that support the operational objectives of PECO Nuclear. These will identify the major safety, performance, and cost goals for Limerick.

Strategic goals are held at the PECO Nuclear level since they encompass the entire PECO Nuclear organization. A strategy manager is appointed to sponsor each goal with accountability to the executive team for the goal's accomplishment. Strategy managers are line managers who act in this collateral duty.

To monitor the progress of the established performance goals, PECO management uses a series of performance indicators. The performance indicators are reviewed monthly at a management meeting at Limerick and other PECO Nuclear locations. The responsible line manager reports on the station goals to peers, the Limerick Station vice president, and the president of PECO Nuclear. This technique assures the goals once established are followed or adjusted as required.

PECO Nuclear uses the quality management process to perform its work. Reinforcing positive behaviour is a key of quality management. To reinforce major goal accomplishment and to identify the need for teamwork to accomplish the goals, Limerick management celebrates accomplishments with the employees. These celebrations range from a single work team that accomplished one of its goals to a site-wide celebration for a successful outage or an operating performance record.

Positive reinforcement is a key for future success. The management meetings where performance indicators are reviewed provide senior management information about goals that are not on track. Management then coaches the responsible individual or organization regarding the need to have a project completed successfully. Limerick's strategy supports the overall PECO Nuclear strategy (Attachment E). The goals to successfully support that strategy are incorporated into a corporate incentive compensation program. The nuclear strategy is revisited yearly in preparation for a business planning cycle.

The performance planning and appraisal process (PPA) establishes the individual accountability for the organization's success. Each individual has specific goals and behaviours that are planned early each year and monitored and rated during the year. These ratings factor into the compensation system and influence salary and incentive awards. An incentive compensation plan puts at risk a percentage of the professional, supervisory, and managerial personnel. Aggressive targets are set to establish rewards for the successful completion of goals, including plant operations. In 1995 the specific targets for Limerick included

- Corporate earnings per share
- Workforce diversity
- Customer satisfaction
- Nuclear O&M
- Capacity factor
- INPO indicator index

A point system is established that allows Limerick and PECO Nuclear employees to earn base and bonus points based on the year's performance. The totals can run as high as 120 percent of target. This translates into an equation for individual rewards which, tied to a multiplier for the individual's performance, establish the incentive award.

US.4.1.3. Management involvement and communication

Management is fully involved in PECO Nuclear and Limerick's accomplishment of established goals. PECO Nuclear's goal is to assure there is not an adversarial relationship between management and employees. Key approaches include continuous communication, union avoidance, working together as a team, and living the core values. The most visible way Limerick management participates in goal accomplishment is through its involvement and participation at the daily leadership meetings. These meetings set the tone for the station. The vice president and his directors attend the meeting and provide support to the station personnel in maintaining a focus on the safety and performance objectives. During these meetings, the senior staff serves as role models for other personnel on how to control operational problems. This active, hands-on role assures the overall focus for the station is maintained while the next generation of leaders is being developed.

The previous section described the method and involvement that PECO Nuclear's executive team takes in goal establishment. As important, PECO Nuclear's management is directly involved in assuring that the overall goals are quantifiable. In 1988 PECO Nuclear management defined world class performance and set a path to accomplish it. These definitions are in Attachment G.

PECO Nuclear management assures that their employees have the resources required to accomplish its goals. Although cost center managers are challenged to reduce their expenses, senior management reviews industry cost trends to establish that the reductions being made will not jeopardize plant safety or performance. PECO Nuclear management also provides its employees opportunities to participate in internationally benchmarking visits to learn from other power plants. The Limerick vice president led two visits to European plants to determine how these plants obtained shorter outages. The techniques learned help support Limerick outage length improvements during the 1990s.

The Limerick communications process provides employees with timely information and encourages employee feedback. Managers and supervisors are expected to ensure their teams are kept current on corporate and station initiatives. A variety of methods are used to communicate information and obtain feedback. These methods include routine team meetings, a phone message and response system, posters and banners, a monthly magazine, and a daily site newspaper.

The Limerick vice president holds an "all supervisors" meetings at least quarterly and "all hands" meetings at least semi-annually. The plant manager facilitates the daily leadership meeting attended by a variety of people, including representatives from all site divisions. The following topics are addressed at the daily leadership meeting:

- personnel and plant safety
- where the plants are and where they are going
- challenges to safe and reliable operation
- exceptions to key indicators
- things that did not go as planned
- what's happening on-site, in PECO Nuclear, and in the industry
- announcements and special topics.

This and other station-wide meetings enable the various station groups to co-ordinate resources and activities and to identify and resolve intergroup conflicts. The meetings typically include managers, supervisors, and individual contributors. Also, an annual survey of employees provides management a measure of the success of their communication. Specific data is provided to each manager.

US.4.1.4. Managing quality

PECO Energy established and implemented a quality assurance (QA) program for Limerick during the plant's design and construction phase. The quality program is an integral part of the plant's operations. It is built on the requirements of the US Code of Federal Regulations Title 10 Part 50 Appendix B. These requirements have been supplemented by a series of American National Standards Institute (ANSI) documents. The Limerick QA program meets the guidance provided by ANSI N18.7 for operating nuclear power plants.

The Limerick QA program is a comprehensive management process that requires all work activities be planned and recorded. Deviations from the plans, a failure of the plan, or an opportunity for improvement require documentation to determine the causes associated with the problem and to identify the appropriate corrective actions. PECO Nuclear subscribes to a QA philosophy that has four levels to assure work is appropriately completed:

- The first level is the person performing the task. This is the most important link in the program. Individuals are trained to perform their tasks accurately and correctly the first time. Continuous self-assessment is expected for all activities using the STAR (stop, think, act, and review process, see Section US.4.1.6).

- The second level is the reviewer, supervisor, and manager. PECO Nuclear's expectation is that all supervisors coach and interact with their employees each day. Techniques include "management by walking around" and a periodic self-assessment process that samples past work practices.
- The third level is the PECO Nuclear quality assurance organization and the plant operating review committee (Limerick's on-site safety review group).
- The fourth level is the Nuclear Review Board and outside oversight agencies, including the US Nuclear Regulatory Commission.

When the third or fourth levels identify a problem, the Limerick quality program has been challenged and a reactive self-assessment is performed to determine why the situation occurred and why it was not identified by one of the first two levels.

Every employee is responsible for carrying out the Limerick QA program. Employees are advised of their responsibilities during initial employee training. The PECO nuclear president has overall responsibility for the Limerick QA Program. The director of nuclear quality assurance (NQA) reports directly to the PECO nuclear president. The NQA director is responsible for providing an independent assessment of selected activities performed by the line organizations.

The NQA organization performs independent assessments (audits), surveillances, and inspections. NQA personnel are qualified to ANSI standards. Assessors are qualified in accordance with ANSI N45.23 and quality control personnel are qualified to ANSI N45.2.6. ISO-9000 is not currently used as the qualification standard for QA personnel because the NRC has not endorsed ISO-9000. For the same reason, ISO-9000 certification for vendors is not used as the sole standard for accepting contractors. Contractors are evaluated against ANSI N45.2 requirements. The quality assurance program of most ISO-9000 vendors meets the requirements of N45.2. Assessments and surveillances performed in a year are

Assessment of Limerick activities	20
Surveillance of Limerick activities	310
Assessment of PECO Nuclear activities	8
Surveillance of PECO Nuclear activities	40
Vendor audits*	24

*PECO Nuclear is a member of a joint nuclear utility organization that evaluates vendors and contractors, so each utility does not have to audit each vendor.

Significant changes have taken place with the implementation of the quality assurance program over the last five years. As the line organization has improved in performing self-assessments, the size of the quality organization has declined. The QA organization had over 150 people in 1990, but has only about 60 people in 1997.

Another significant change that allowed this reduction was a "quality to the line" philosophy that began in the late 1980's. Several areas were targeted as part of PECO Nuclear' NEEDS program in 1992; see Section US.4.1.1. As part of the NEEDS effort in-line QA reviews were eliminated from several activities that are the line's responsibility. These activities included selected maintenance inspections, procurement document review, non-conformance report closure, corrective action report closure, receipt inspection, radwaste inspections before release for shipment, and procedure reviews.

PECO Nuclear uses a quality management (QM) program that was introduced in 1990. Limerick employees were trained in the QM technique in the early 1990's. PECO Nuclear's QM Program is based on six quality principles. They are

(1) Satisfying customer expectations
(2) Fostering continuous improvement
(3) Empowering employees through teams
(4) Making decisions by fact
(5) Recognizing and rewarding performance
(6) Linking improvement efforts through business planning

The QM continuous improvement cycle is the heart of the program and is practised regularly at PECO Nuclear. All PECO Nuclear employees use the APIR (assess, plan, improve, and reinforce) when establishing a project or work activity.

US.4.1.5. Relationships with contractors

The number of contractors on site was reduced following commercial operation of Unit 2. Contractors provide the security forces and radwaste technicians. The bulk of the others are either filling vacant utility billeted positions, until such time as a full time employee is hired, or working on a special project with a definite time frame.

At Limerick contractors play a significant role in its success and even with declining numbers have sustained a level of importance in the organization. To support this objective Limerick management and staff works with the contractors to understand the vision, mission, and values, as well as the operational objectives and goals that support these. A copy of the specific goals and objectives are supplied to the contractors. Contractors are held to the same standards as the utility employees and must meet the following expectations:

- Perform all work safely
- Perform all work efficiently
- Perform all work within established station procedures, practices, and guidelines
- Provide a quality product
- Manage radiation exposure — ALARA
- Keep work area clean
- Communicate needs, expectations, problems, and progress
- Self check all work.

The number of outage contractors varies to some degree depending upon the outage scope and how much work utility employees can do. There are specific jobs that are contracted out, such as insulation, condenser cleaning, scaffolding, painting, and work requiring drivers. Over the years the number of contractors supporting the refuel outages has ranged between 800–1800 depending on the scope of the work.

The contractor management teams participate in all station meetings and are held accountable for their safety, work scope, communication issues, etc. The site makes every effort to involve each contractor so they feel the same responsibilities, pressures, achievements, rewards as an utility employee. This has resulted in shorter outages and improved overall operating performance, competitive bidding, increased customer satisfaction, and jobs performed safely.

US.4.1.6. Budget and resource allocation

The budget process begins with PECO Nuclear being given a overall budget target which in turn is allocated to each location based on historical data and known work scope for the site. The budgets are prepared for a five-year period.

Once the site receives the budget allocation each department is given a budget target not to be exceeded if at all possible. If the budget target is exceeded, the site management team works to reduce the budget to the target level. There is an exchange of ideas, resources, and, at times, dollar allocations. Any deviations from budgets must be justified to senior management, who may or may not approve.

Directors reporting to the vice president are held accountable for their budget each year. A review is done with each team on a quarterly basis to see where the budget stands and what is forecast for the remainder of the year so that necessary corrective measures can be taken. There are times that additional budget reductions are necessary to support the corporation in meeting earnings for a particular year or cost over-runs by another department. In some organizations the manager or first line supervisor is held responsible for their piece of the budget. It is part of the overall plan to push responsibility into the organization. This has worked well.

While budgets have been reduced to be competitive, the goal has been an operating and maintenance cost of less than one cent per kilowatt-hour (without fuel). The inevitable deregulation of the market was a factor in beginning the process to generate at less than one cent per kilowatt-hour. The program at Limerick became known as the "penny crusade." Attachment F shows the O&M budgets for the years 1991 through 1996 broken down by organization with notes of major changes.

US.4.2. Personnel

US.4.2.1 Personnel characteristics

Limerick has a staff of 785 full-time employees supported at the site by 75 long term contract workers primarily in security and radiation protection. The plant shares offsite nuclear corporate headquarters support of approximately 250 full-time engineering, information systems, programmatic, fuels, and licensing employees. In addition, there are 280 mobile nuclear maintenance utility employees who support outages and routine maintenance work. These mobile employees devote approximately 35 percent of their man-hours to support Limerick. The site organizations are supplemented during refuelling outages by a labour force of up to 1500 craft and technical personnel. Organizations are similar in function and structure for all PECO Nuclear plants. This allows for sharing best practices, better communications, and a better distribution of work. A 1995 study showed that Limerick and its support organization staffing were in the lowest quartile in the US nuclear power industry in most functional areas.

The Limerick workforce has shown a significant reduction from 1694 in 1992 to 1144 in 1995. There have been many innovative strategies that allowed Limerick to achieve low staffing levels. These strategies include

- Cross training the maintenance workforce, including advanced radiation worker practices, mechanical and electrical craft teams, equipment release by craft workforce, and fix-it-now teams

- Detailing outage and non-outage schedules, including a commitment and accountability to meet the schedule
- Centralizing turbine and reactor teams
- Accepting responsibility for being competitive
- Reducing the amount of capital construction
- Pooling clerks and providing administrative controls
- Moving activities into the line organizations.

PECO Nuclear recognizes the need to have a well-educated, highly trained, skilled and dedicated workforce and has programs to recruit, train, and promote its employees. At PECO Nuclear, there are two general classifications of employees: craft-technician-administrative-clerical (CTAC) and professional-supervisory-managerial (PSM). Approximately 55 percent of the employees are CTAC and 45 percent are PSM.

In the CTAC group, significant training is provided at the Limerick training center. Initial and continuing training is given to the plant operators, health physics personnel, chemistry and maintenance technicians, and other groups. To improve the overall work flow and reduce the number of handoffs during an activity, PECO management reduced the number of maintenance categories from 13 craft categories to 5 technician categories. This change required significant training but has achieved its goals. The Limerick refuelling outage length went from 100 days in 1990 to 23 days in 1995. The ability of the maintenance group to complete jobs without making several handoffs has contributed significantly to that reduction.

In the PSM group, job-related training is also provided on an initial and continuing basis. Typical examples include senior reactor operator training and engineering training for both design engineers and system managers. In addition, significant training is provided for supervisors and managers. PSM employees have been trained in quality management to ensure they understand the management philosophy. To further develop skills for all employees, college level courses are offered on site, including a Masters of Business Administration program, undergraduate degree program, and the shift worker degree program. For those pursuing offsite education, tuition reimbursement is provided for people pursuing a college degree.

Hiring new employees has been limited. When staffing needs occur, a primary recruitment source has been the US Navy. These individuals come with previous nuclear experience. Since 1991, PECO Nuclear has hired only one manager from outside the company at or above the plant manager level (that individual is currently on loan from INPO and is the vice president at Peach Bottom Atomic Power Station).

For technical personnel, PECO management has identified the types of experience employees need to advance as supervisors. The policy is geared to obtain well-rounded supervisory personnel who can evaluate the impact of their decisions of all aspects of the business. PECO Nuclear also has a career rotation program for technical professionals. This program allows individuals to self-nominate for rotational assignments within PECO Nuclear. From this list, management transfers several employees each year to other work assignments either at their existing job location or to another location within PECO Nuclear to gain experience. These rotational assignments usually average two years.

To provide personnel with additional outside experience, PECO personnel take part in INPO assistance visits and evaluations, NEI benchmarking visits, joint utility management audits, and visits to other plants. The plant visits include plants inside and outside the US.

Limerick has learned extensively from foreign plants. In the early 1990's, Limerick exchanged visitors with the PAKS plant in Hungary. Limerick personnel visited plants in Switzerland, Finland, and Spain to gain experience with shorter refuelling outages.

US.4.2.2. Personnel development and training

Employees assume primary responsibility for personal development and career growth. Management provides an environment and resources that reflect the values and processes of a learning organization. Training needs are primarily defined by the job requirements and include both technical and behavioural areas of competency. There is a recognition of the link between a well-trained workforce and the safe operation of the plant.

The strategic movement of employees supports PECO Nuclear objectives of attracting, motivating, and developing a highly committed, competent, and professional workforce. The training conducted on the job provides experiences that are critical elements in professional development. These varied job experiences cultivate the organizational sensitivity necessary to achieve the high level of understanding and communications imperative for the long term success of the organization. This "hands on" understanding of the organization is a major factor in bringing PECO Nuclear to its vision of becoming the best. Professional development assignments drive career enhancement and advancement. Diverse work experiences at multiple locations have become increasingly valued and required in the assessment of employees for promotion to supervisory and managerial positions. PECO Nuclear management requires these varied experiences and sustained strong performance before promotion.

The line organization is accountable for the training and development of their staff. Line supervision and employees work with the training organization to identify areas that need attention and to provide customer feedback on the effectiveness of programs. Supervisors have a great deal of input in continuing training and they use "just in time" training for complex or infrequently performed jobs. The annual self-assessment process and performance reviews are two formal ways to identify both individual and work group needs. At least two ongoing methods — job critiques and performance enhancement program items — capture specific areas for improvement in technical knowledge and skills.

Limerick management believes that continuous learning is necessary (one of the PECO energy's core values). In addition to the training opportunities provided to individuals, management has established systems that foster continuous learning. They include

- Self-assessment — This is a way of life at Limerick. It starts with each individual using STAR (stop, think, act, and review)
- Learning from PECO experiences
- Learning from other plants experiences
- Benchmarking
- Past evolution critiques

The training organizations and the individual line organizations have developed performance indicators to measure the success of the training. The budget for the site training organization is about 3.5 percent of the total O&M budget, excluding the lease cost of the simulator, students' time, and training provided by the corporate organization.

The various training modules are modified to meet organization and employee requirements and requirements for new standards and equipment. On a regular basis the training department seeks feedback from the students and managers on instructors, course content, and training effectiveness. There are signoffs by supervisors or instructors for performing learned tasks to successful performance in the field.

Training is designed to meet both the criteria established by the National Academy for Nuclear Training and to emphasize commitment to excellence, safety, and continuous improvement. To provide the best possible training environment, the following expectations for instructors and students have been established.

Instructors are expected to

- Be technically prepared
- Be responsive to the academic needs of the students
- Provide leadership during training sessions
- Be open to suggestions for improvement

Students are expected to

- Be physically and mentally alert, attentive, and receptive to the training materials
- Raise questions that contribute to their understanding of the training materials
- Complete class preparations, quizzes, tests, exercises, and exams
- Report concerns regarding instructional matters to the instructor, to the training supervisor or to line management.

PECO Nuclear utilizes the INPO training system development (TSD) approach for performance-based training. This process is a five-step system:

- *Analysis* — Analyse job tasks to determine which tasks require training to assist in proper performance.
- *Design* — Determine how to best train students on each task or concept and establish objectives with corresponding test items.
- *Development* — Assemble and organize all necessary training materials to support the desired learning activities and objectives.
- *Implementation* — Present the course: Instructors are selected, resources are confirmed, and facilities are finalized.
- *Evaluation* — Monitor the effectiveness of the training based on its effect on the trainees (e.g., the trained individual's job performance and the plant's operating experience). The indicators are then used to update the training.

The training department at Limerick consists of approximately 55 people, with some in rotational positions to take advantage of individuals with plant experience and abilities to teach others. There are other departments within PECO Energy providing training for supervisors through "Leadership 2000." Other supervisor training programs include the supervisor development academy for new supervisors, supervisor development institute for experienced supervisors and managers, and leadership exchange series at the director level and above. Also there are on and off site degree programs.

Despite the reduction of personnel and budgets, the performance of both training and the station has improved significantly. Training has improved plant performance in several key areas:

Operations

- Focused, effective, needs-driven simulator training has contributed to successful operator response to plant transients.
- The simulator is frequently used to train and test infrequently performed tasks and off-normal plant manipulations.
- Sponsorship of LSRO on-the-job training has supported continued error-free performance of core component movements at PECO Nuclear, exceeding industry averages for efficiency and operational excellence.
- Simulator work requests (SWRs) are reviewed by the simulator action review committee (SARC), a team made up of members from the simulator support group, operations training, and operations shift management. This results in the effective prioritization of work and the continuous improvement of simulator fidelity.

Engineering support personnel (ESP)

- The integrated plant operations (IPO) course provides experienced system managers, engineers, and supervisors with a training experience in the simulator setting. Training emphasizes the design bases for plant response and procedural direction in response to transient and accident scenarios.

- Case study analysis of operating experience emphasizes lessons learned at Limerick and in the industry and has resulted in a high level of student participation.

Services

- Computer based training for GET requalification has provided scheduling flexibility to meet plant access requirements. It allows individuals to complete training with minimal impact on their, or the instructional staff's, schedules.

- Basic radiation worker training was expanded to incorporate more in-depth coverage of contamination control practices. Working RADOS readers, small article monitors (SAMs), electronic dosimeters, and a review of work orders were incorporated into the practical factors training. Addition of these items and use of the work order has made the practical exercises more realistic and comprehensive. In addition, the basic radiation worker program was changed to require all contractors who had not worked at a PECO Nuclear facility within six months to successfully pass the practical factors training. The overall result of these changes was an improved radiation worker performance during the most recent refuelling outage, as indicated by fewer plant contamination reports (PCRs), worker performance problems involving radiological controls, and problems associated with worker use of the electronic dosimetry system.

- Vendor health physics (HP) training has expanded to include additional performance evaluations utilizing a job scenario. Extensive support from plant personnel was provided in evaluating contractor qualifications.

Maintenance and instrumentation and control (I&C) training

- Cross training of station personnel in maintenance and I&C tasks has resulted in improved work efficiency and less dose exposure. Some examples of cross training are (1) local leak rate test training provided to non-maintenance personnel and training personnel for additional outage support; (2) torquing and basic precision tools training provided to HP technicians; and (3) valve and instrument packing and adjustments provided to HP and operations members of the FIN (fix it now) team (see Section US.4.3.1).

- Preventive maintenance work can be performed and equipment operated using actual plant work order processes for performance and documentation of work activities during training sessions. Use of innovative training methods, and increasing the amount and quality of training provided to contractors for outage support has improved training effectiveness and resulted in better contractor performance during outages.

Training support and facilities

- Development and use of multimedia presentations, high quality video productions, and innovative training methods have improved overall training effectiveness and produced manpower savings.

- Training effectiveness has been improved by upgrading training facilities, including the welding qualification area, the addition of a mock-up building, and the following mock-ups: motor control center, motor-operated valve, MSIV, recirculation pump seal, and electrical relay panel.

US.4.2.3. Personnel behaviour and attitudes

PECO Nuclear has recognized that personnel behaviour is critical to achieving a well performing plant. When PECO Nuclear formulated its initial strategic plan and operational objectives in 1988, a set of behaviours, or values, were included. The values identified were safety, quality, dynamic business focus, teamwork, people, and integrity. With the 1995 PECO Nuclear poster, a slight modification was made to the values with competitiveness replacing dynamic business focus. This was done to more accurately reflect the environment in which utilities operated.

In 1992, PECO Energy modified the corporate performance planning and appraisal (PPA) System to recognize that behavioural values are key drivers of overall performance. A percentage of each professional's and supervisor's rating was based on their behaviours. During the planning, the individual identified selected behaviours that were critical to their success and identified what characteristics they wanted to exhibit. Throughout the year, the individual's supervisor provided feedback on how the individual was exhibiting the behaviours through the PPA process. The nuclear values were a part of the behaviours identified in the PECO Energy competency model that was included in the PPA process. This information was further refined and a set of core values, called the PECO Energy advantage, was published in 1995. PECO Nuclear and all other divisions of PECO Energy now use the same behaviours as the guiding principles for all activities. Each core value (see Section US.4.1.2) is supplemented by guiding behaviours that provide employees a model for their actions.

At PECO Nuclear safety is the first and primary value. This includes both nuclear and personal safety. Results from both internal and independent evaluations repeatedly identify the overriding concern employees have for safety. The workers attitudes are reflected in the high nuclear safety that Limerick has achieved. The INPO composite index for Limerick has been at or above the industry average. Limerick's personnel safety record was significantly improved from 1992 to 1995. The lost work day incident rate went from 2.06 to 0.12. (lost work day incident rate is the number of lost work days or restricted duty days multiplied by 200000 and divided by the number of man-hours worked.) This improvement occurred because line management emphasized the importance of safe work practices and reinforced the safety practices in pre-work activity briefings.

A self-assessment philosophy is ingrained at Limerick. In 1991, PECO Nuclear issued its self-assessment policy and handbook. There are four types of self-assessments used at Limerick. They are continuous, periodic, reactive, and pre-emptive. The continuous self-assessment technique is described in Section US.4.1.4.

- *Periodic* self-assessments start with the work team reviewing a portion of the work performed to ensure it meets management's expectations. The results are consolidated by each organization to look for common opportunities. The consolidation culminates with a station summary that again looks for common opportunities for improvement. The Limerick vice president and his staff then endorse these opportunities.

- *Reactive* self-assessments are performed at Limerick when an organization finds a problem that the responsible organization did not find or when the organization is surprised by the results found. Reactive self-assessments not only look to correct the cause of the problem, but to learn why the line organization did not discover the problem.

- Limerick performs *pre-emptive* self-assessments to determine if the planned change has incorporated the necessary steps to resolve potential problems. The technique has been successful in strengthening project plans.

Developing a questioning attitude has been one of the behaviours that is fostered and encouraged at Limerick. The executive team during the Nuclear Review Board meeting (the offsite safety review committee) models this behaviour. The WHY staircase is used to determine how the root causes of issues are uncovered and corrected.

The performance enhancement program (PEP) investigates and critiques safety-related issues, daily operations, human performance issues, and near misses. This program resides in the PIMS computer system. All work groups have access to the process and communicate to experience assessment through this medium. The program methodology encourages the self-identification of plant operations issues. This self-identification reduces the likelihood of an external agency or oversight group making a significant finding. This promotes a continuous improvement attitude demonstrating to the regulatory agencies that Limerick has an effective process for handling errors in the normal operations of the plant.

Finally, Limerick uses the operating experience assessment program (OEAP) to review the problems that other nuclear units encountered and to determine if they could affect Limerick. If judged to be applicable to Limerick after they are reviewed, corrective actions are taken so the problem cannot occur at Limerick.

US.4.3. Working practices

US.4.3.1 Plant status control

Plant status is continuously monitored on each shift in both the main control room (MCR) and plant areas. This activity is the primary responsibility for both reactor operators and equipment operators. reactor operators perform plant monitoring in the MCR at various plant monitoring system (PMS) consoles and panel displays to determine trends and to detect equipment problems. Equipment operators monitor general operating conditions in the operating areas of the plant. Operating status is monitored in the MCR and operating plant areas through observation of equipment, controls, and displays. Monitoring is increased for any degraded equipment. Abnormalities and frequent updates are reported to the shift supervisor and shift manager for status monitoring and resolution.

Equipment operators perform their rounds during each shift by touring operating areas to assess plant conditions, monitor system performance, obtain technical data on plant process parameters, and make minor adjustments to plant systems. Equipment operators enter rounds data into hand held personal computers (PCs). Reactor operators perform shift log updates using surveillance test procedures (with input from equipment operators) to record critical plant parameters and verify that the readings are within acceptable ranges. Both forms of data are reviewed each shift by a shift supervisor to confirm that all data is within acceptable limits and to ensure deficiencies are identified.

Operators, during their plant monitoring activities, identify equipment deficiencies and abnormalities. These items are documented on an equipment trouble tag (ETT) and forwarded to shift supervision for immediate evaluation and approval. ETT items are entered into the plant information management system (PIMS), which is used for all station work performance. ETT tags are hung at the deficient component and at the appropriate MCR panel or console location to clearly identify the deficiency. ETT tags are removed after corrective maintenance is completed and the component has been returned to service. MCR deficiency items receive the highest priority for resolution (by procedure) in the station work management process and are monitored by station management to minimize the number of MCR alarm and annunciator +++anomalies. MCR deficiencies typically have a short duration since many are completed within one to two days through the fix-it-now (FIN) process. The FIN teams consist of a cross-functional group of employees who can work on many systems in the plant and make repairs quickly. These teams address problems before they develop further. During slow periods, each FIN team has a list of jobs, thus reducing the work for regular maintenance teams.

The shift manager, shift supervisors, and reactor operators enter updates into the unified control room log (UCRL). This is a PC database of plant information accessible from all MCR PC's via the station local area network (LAN). MCR personnel routinely enter plant status and key parameter updates into the UCRL. In addition, MCR personnel record log entries for specific or significant occurrences (such as start of shift, startup or shutdown of plant equipment, reportable events, entry into abnormal or emergency procedures, equipment or systems removed or returned to service, major equipment maintenance and testing in progress or completed, and significant ETTs generated). In addition, a shift supervisor enters inoperable equipment and systems into the limiting condition of operation (LCO) log or potential LCO log.

Extensive turnover of information is performed each shift for each member of the operating crew. Turnover information includes abnormal rounds data, plant parameters, system status, equipment status, panel walk-down, UCRL review, LCO/PLCO review, and a review of daily shift night orders (SNO) that highlight specific operations or station initiatives. Other turnover tools include a shift manager end-of-shift plant status report (voice mail). Also, there is a daily shift manager turnover meeting with the operations clearance and tagging contact to review and prioritize plant equipment deficiencies for resolution.

A log of all temporary modifications is maintained in the MCR. These are classified as temporary plant alterations (TPAs). Station management monitors the use of TPAs to assure TPAs are minimized. This reduces the number of abnormal plant conditions. Typically no more than ten TPAs exist at the station. The TPA log is reviewed each shift by a shift supervisor.

US.4.3.2. Operations

US.4.3.2.1. Operating procedures

Procedure usage and compliance are core expectations at Limerick for all station personnel. This is especially critical for success in plant operations. Operations personnel are expected to (1) review each procedure before usage, (2) maintain the procedure in hand at all times during performance, (3) check off each procedure step as performed, and (4) verify response (system, component, or indication) as expected. These four steps are part of the event free operations (EFO) Program that utilizes a checklist pocketsize card to identify specific behaviours for success in plant operations.

If a procedure cannot be performed as written due to plant conditions, procedure inaccuracies, or special situations, operations personnel obtain approval for a procedure change before using the procedure. These changes can be implemented via a temporary change (TC) request or a permanent revision. TCs can be used for unique (single or multiple use) changes or permanent changes. TCs are immediately updated in the MCR. Permanent revision requests are tracked in the PPIS (plant procedure enhancement system) database (located in the station PIMS system), revised by appropriate station personnel, and reviewed and approved by station supervisor. Review and approval can be done by a station qualified reviewer (SQR) who is technically knowledgeable with the affected procedure, the responsible superintendent, or plant operations review committee (PORC). A review of safety questions is typically required for all procedure revisions. This review consists of a four-question determination (screening) and an evaluation (if required).

The quality of operating procedures was improved through the human factoring and procedure partnership initiatives. Human factoring was implemented on all operating procedures to achieve consistent procedure appearance, formats, and usage of action verbs, notes, and cautions. Procedure partnership involved a joint walk-through of each operating procedure by the cognizant system manager and an assigned operator. The partners identified inaccuracies and proposed improvements to each procedure to improve procedure accuracy and optimize the procedure steps for efficient performance.

Procedure revisions are initiated by various programs, including industry event reviews (INPO operating experience assessment report — OEAP), station learning experiences, modification related changes, the PPIS process, licensing changes, internal and external commitments, incorporation of temporary changes, and others. OEAP and licensing changes are triggered by notification from the station operating experience assessment report group. Station learning experiences include those changes identified by the performance enhancement program (PEP, see Section US.4.3.2.3), internal quality assurance and independent safety engineering group (ISEG) reviews, and station chronic system/equipment problem program. Modification related changes are identified in an engineering change request (ECR) process and include minor design changes, large scale modifications, temporary plant alterations, and others. The PPIS program includes a call-in telephone hotline for station personnel to quickly report procedure enhancements. Procedures training needs are evaluated for each revision. Procedure revision training is accomplished with training bulletins (read and sign) or classroom instruction. It is commensurate with the degree of the scope change. Classroom instruction is conducted before the procedure revision effective date.

Some procedures contain flow charts or lists. These document revisions are controlled and processed as part of the associated procedure revision request. Transient response implementation procedures (TRIPs) are emergency operating procedures in flow chart format that are used for operator response to emergencies and initiating events that could degrade into more serious emergencies. Each TRIP procedure or chart has an associated basis procedure. The chart and associated procedure are revised and approved in tandem to ensure consistency and accuracy.

Control room licensed operators use symptom based emergency operating procedures. These procedures are in flow chart format and entered when critical parameters exceed normal values. Being symptom based eliminates the need to diagnose the cause of the emergency condition. Actions are designed to control the parameter of concern.

These procedure programs, practices, feedback systems and expected adherence promote continuous improvement of procedure use and ensure that the operating procedures are accurate and appropriate. These processes and policies minimize human performance errors and station events, ensure timely and effective response to abnormal plant conditions, and maximize plant availability.

US.4.3.2.2. Operating aids

Operators use various computer systems to facilitate control of plant to log activities, to record data, to schedule activities, and to access industry experience. The operators have access to the LAN where they can use the standard PC programs such as word processing, email, spreadsheets, database, and presentation programs. From the LAN the operators can connect with mainframe applications such as PIMS (plant information management system).

PIMS is used to initiate and manage many action items. Action requests (AR) are initiated for equipment deficiencies, commitment tracking, improvement initiatives, and other forms of action tracking activities (self-assessment, outage critique, etc.). The work planning and scheduling organization uses the AR to generate supporting documents to remove and restore equipment for maintenance and testing. The operators also use PIMS to access the equipment database, order materials, and check on the status of equipment deficiencies and maintenance activities. PIMS is used to manage the human performance enhancement system and event investigation process. This permits sharing information among work groups throughout the company.

Operating procedures and surveillance tests are available electronically via lotus notes on the LAN. Hard copies are also provided and controlled in the main control room and station library. Selected procedures are provided for equipment operator use at equipment locations. By providing hard copies of procedures the operators have the proper operating instructions, cautions, warnings, flow diagrams, and past failure experience at the equipment location. The procedures have been human factored to be accurate, simple, and user friendly. Operators were teamed with system managers to review and approve the procedures before implementation.

Component labelling deficiencies are tracked in PIMS via AR's and replacement labels can be printed from the equipment database in PIMS. Labels are colour coded by unit and all plant areas are colour-coded. Operations support administers the labelling program. Plant equipment has been labelled extensively. Unlabeled components are brought to the attention of plant supervision and corrective actions are initiated.

Some components have been provided with plastic covers to prevent inadvertent actuation. Reactor recirculation M-G set relays are protected by such a barrier. The control rod select matrix is covered during some refuelling activities and the reactor water cleanup filter Demineralizer control panel has a barrier over the operating F/D controls. Some critical equipment is locked in position. Logs are used to track the release and restoration of the components. Other components are locked to facilitate clearance application in inaccessible areas, in these cases the key can be tagged as the controlling point.

US.4.3.2.3. Other programs and procedures

(1) Limerick operations review board (ORB): A group of operators meets weekly to discuss and solve problems faced by the operating crew. The group is lead by an off-shift equipment operator. They are empowered by the operations manager to make or change operations policies and work priorities to improve operator working conditions. The group identifies plant improvements needed for operator safety and effectiveness. The group has senior management sponsorship to assure priority issues are resolved in a timely manner. Issues that are identified as priority items by the group are monitored until resolved by the team.

(2) Event free operations (EFO) program: This program identifies and reinforces operator attributes (behaviours) that have improved plant operations. The attributes were developed by a team of operator representatives from each shift crew. A blue observation card listing the EFO attributes is completed for self-assessments, peer observations, and supervisory observations. These observations focus and strengthen the use of the EFO attributes during daily operations. Operators also use the blue card as a self-check guide (checklist) before performing a task. This program has resulted in significant reduction in operational events. Events resulting from human error have decreased from 13 per year in 1994 to 6 per year in 1996. No events have occurred through April 1997. The 1997 EFO goal is 4 events or less.

(3) PEP program: The station human performance system is called the performance enhancement program (PEP). This program utilizes an investigative process to identify the root causes of issues, implement corrective actions and lessons learned, and perform corrective action effectiveness reviews. After a human performance or equipment performance issue occurs that meets a department's PEP threshold criteria, an investigation is triggered by initiation of a PEP document in the PIMS mainframe system. Many of the issues are self-identified. Self-identification of learning opportunities is encouraged. Operations personnel use the EFO program as an antecedent to human performance errors by focusing on behaviours that will minimize those errors.

(4) Equipment control and work release: The station's work authorization is divided between the MCR and a services group of operators on yearly rotation. This minimizes distractions in the operation of the plant and maintains efficient, timely work release. Control of equipment and isolation boundaries for minor work is achieved by using do-it-now (DIN) by all employees, for more complex work a fix-it-now team process, and a clearance & tagging process for normal maintenance activities. The C&T program facilitates safe, efficient work through a combination of master and sub-multi-step clearances (tailored to the workflow) that uses special condition tags (SCT) and work group tagging. This enables maximum worker flexibility with minimum tagging, while allowing for contingencies.

(5) Station predictive maintenance, preventive maintenance, minor maintenance: The station predictive maintenance, preventive maintenance, and minor maintenance programs contribute to reliable plant operation by providing effective monitoring of plant equipment, early detection of component degradation, and the ability to quickly repair minor deficiencies. Predictive maintenance is comprised of vibration monitoring, oil sampling, thermography, performance monitoring, motor-operated valve testing, and other programs. Preventive maintenance is directed at preventing in-service failures by performing appropriate maintenance at the optimum frequency. The station utilizes a fix-it-now (FIN) team to perform minor maintenance. The flexibility and team composition allows the FIN team to absorb the majority of emergent work issues. This results in a minimal interruption to the daily work schedule while increasing equipment availability and reliability. In addition, a do-it-now process is used for minor adjustments and parts replacement on non-safety related components.

US.4.3.3. Maintenance

The maintenance organization has made a significant change by reducing the number of crafts from 13 to 5. This is one of the ways in which the number of people, as well as the number of hand-offs to complete a job, has been minimized, thus allowing for shorter maintenance time. Along with this change, the ability for Limerick to remain union free has provided the flexibility to make these changes in a reasonable time without compromising quality, safety, or timeliness.

The use of mock-ups for equipment that may be located in high radiation areas or require special training has improved the efficiency with which some jobs are performed and has reduced exposure. One other innovation is the use of a surrogate tour on video laser disc. This can familiarize workers with areas they may have little or no experience.

The maintenance planning organization along with a work week co-ordinator schedules work at least five weeks in advance. As with most of Limerick's processes, there is a performance indicator (PI) that measures a foreman's weekly performance and a summary PI showing completion percentage on a weekly basis. Maintenance has a significant number of PIs that measure corrective and preventative maintenance backlogs, completion, amount of re-work, work that requires rescheduling, and work quality. The maintenance organization has embraced the concept of line accountability for work quality. This has become part of their culture and quality has improved.

US.4.3.4. Technical support and other activities

A unique aspect of Limerick is the position of system manager (SM). This position is an extension of the typical system engineer found at other sites, but the role is far more important at Limerick. These system managers have total control of their respective systems, including (1) deciding what modifications are to be completed; (2) determining what maintenance is to be performed during an outage; (3) co-ordinating, scheduling, and planning work activities; and (4) integrating the predictive maintenance program. Component engineers are integrated with the system managers and work primarily in a support role.

The SM has helped focus engineering support for operations and maintenance. The system manager takes an active (cross-discipline) role as team leader in problem solving during both outage and plant problem events. Engineering has taken a strong role in performance monitoring, both from a system functional perspective and in the utilization of advanced system engineers. system managers do not do tech-spec performance testing. Testing is accomplished solely by operations and maintenance employees. The system manager's key functions are

- *Work management*: The system manager integrates a six-week look-ahead and system outage window process.
- *Troubleshooting*: The system manager is the focal point of solution teams for all maintenance, operations, and safety issues dealing with his system.
- *Assessing system health* (using the chronic problem process): The system manager can use any of the following aids to perform this function: system notebook, monthly self and customer system grading system, system walk-down log, list of outstanding work orders, problem identification reports, system outage window schedule, and planned work.

US.4.3.4.1. Technical aids

(1) Modification manual: The modification manual is a detailed, prescriptive procedure of approximately 300 pages that provides administrative guidance for both the Peach Bottom and Limerick plants. It starts with the initiation of a modification and goes through closure. The table of contents contains eighteen sections, beginning with "modification process overview" and ending with "modification closure." Other sections deal with initiation and approval, responsibility matrix, alternative analysis (alternatives from doing nothing to full modification), project planning, simulator impacts, walk-downs, test development, training, etc. In the overview section, modifications that can be accomplished by limited scope procedures are listed, such as design equivalent changes, computer software changes, temporary plant alterations, and minor physical changes.

(2) System manager tools: Limerick's implementation of the SM concept and its ability to improve productivity has been supported by developing numerous tools:

- SM notebook — a standard data filing system
- SM turnover checklist
- Shift Update Notice (SUN) — formalized engineering information to shift operators
- Weekly system walk-down checklist
- System report card measuring qualitative guidelines
- Annual system report
- PERMON — LAN-based performance monitoring software
- SM responsibility list
- Daily work co-ordination process

The SM notebook is a formalized and standardized filing system that establishes a minimum information reference base for each SM. The system notebook improves the ability to train new system managers and to access needed information quickly, especially during periods when the primary SM is not available. A simple but very useful tool is the SM responsibility list. This is a matrix that lists each system, current SMs, backup SMs and previous SMs, and provides the current SM supervisor with addresses and telephone numbers.

US.4.3.5. Interaction between work groups

The plant management team interacts with the staff through a variety of methods. Communication methods include meetings, the automated message system, posters, a magazine, and site newspaper. The Limerick vice president holds supervisor meetings quarterly and an All-Hands meeting semi-annually. The plant manager leads the daily leadership meeting attended by representatives of all site divisions. Performance indicators are reviewed weekly at leadership meetings. Communication with employees regarding the performance indicators and the role of each individual is stressed.

During an outage, there are a series of daily meetings of key Individuals at 7:00 AM, 8:30 AM, 11:30 AM, and 3:00 PM to communicate key messages and allow for the open discussion of obstacles, safety, and over all status. "make-it-happen" managers are chosen for key milestone and projects throughout the outage. A shift outage director maintains 24-hour leadership responsibilities for conduct of work.

The workweek management process is used to accomplish station non-outage work. This process involves the identification, planning, and conduct of modification, maintenance, and testing activities. This is supported by the plant information monitoring system that integrates all key work systems at the site, including work orders, materials, radiation controls, plant equipment release, security, and other action and information tracking modules. The senior outage manager is responsible for this process. Other responsible individuals include workweek managers, unit co-ordinators, and representatives of all plant disciplines. All group activities that contribute to the work management process can be found in the monthly performance report. Process improvements can be tracked to cost savings. Productivity improvements can be tracked to daily and outage work.

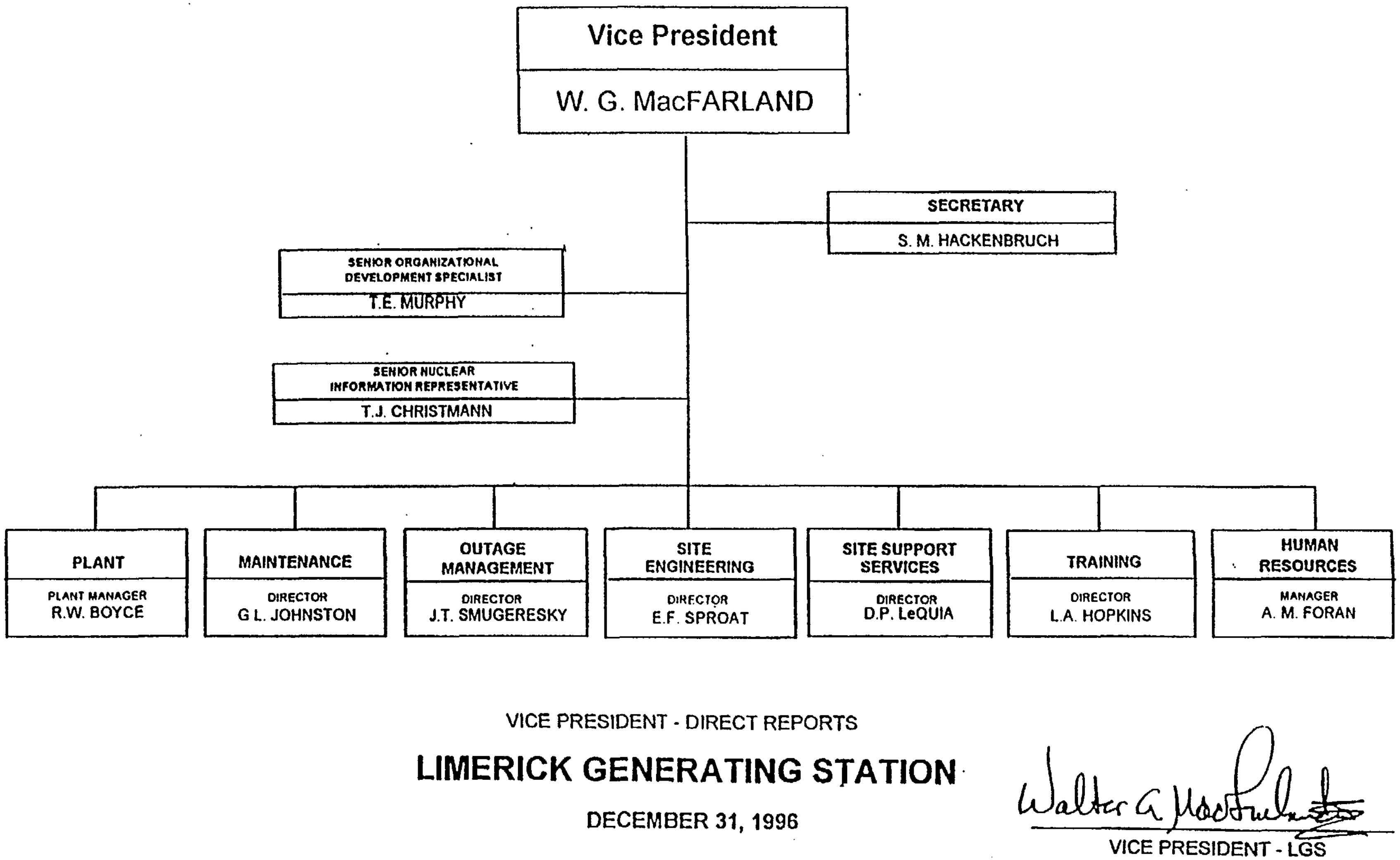


FIG. 1. PECO Limerick organization chart..

PECO NUCLEAR
A Unit of PECO Energy

Limerick
Generating Station
Senior
Management
Report

DECEMBER 1996

Performance Indicator Summary

FIG. 2. Senior management report.

PECO ENERGY

PECO NUCLEAR
BUSINESS REPORT

December, 1996
Performance Indicator Summary

FIG. 3. Nuclear group business report.

Limerick Generating Facts

	1989	1990	1991	1992	1993	1994	1995	1996
PRODUCTION								
Station Net Generation	5,214,000	12,854,000	15,275,118	14,718,243	16,213,903	16,431,000	16,549,000	17,142,725
Station Capacity Factor	56.4%	70.51%	82.64%	79.41%	87.71%	89.90%	87.06%	87.91%
Station Forced Outage Rate	0.0%	8.5%	4.8%	5.8%	1.9%	1.0%	3.7%	4.2%
Capability Factor	60.0%	70.7%	82.5%	81.1%	89.3%	92.6%	89.0%	89.2%
Unplanned Capability Loss Factor	N/A	N/A	6.6%	7.0%	3.1%	1.9%	4.87%	5.74%
U/1 Refuel Scheduled Days	N/A	N/A		70		42		22
U/1 Refuel Actual Days	127	100		111		35.9		24.6
U/1 Refuel Outage Budget $	N/A	N/A		$ 32.50		$25.1		$20.1
U/1 Refuel Outage Actual $	N/A	N/A		$ 27.90		$23.3		$22.1
U/2 Refuel Scheduled Days			70		68		29	
U/2 Refuel Actual Days			74		53		22.8	
U/2 Refuel Outage Budget $			$19.8		$28.4		$23.2	
U/2 Refuel Outage Actual $			$18.9		$25.9		$20.8	
COST								
LGS O&M Budget $	$113.7	$112.3	$113.8	$120.3	$124.1	$120.3	$116.6	$112.5
LGS O&M Actual $	$117.6	$111.7	$113.6	$121.2	$122.6	$116.3	$115.6	$111.6
Capital Budget $	$45.2	$81.4	$53.9	$54.2	$52.9	$46.2	$37.7	$32.8
Capital Forecast $	$52.0	$60.0	$40.0	$55.1	$48.1	$45.2	$39.6	$31.3
Capital Actual $	$37.2	$66.1	$31.9	$57.9	$47.4	$46.0	$39.4	$30.6
Total O&M Budget $	$183.9	$190.9	$182.9	$187.6	$190.0	$181.5	$171.1	$170.6
Total O&M Actual $	$192.1	$167.6	$185.3	$197.6	$188.3	$173.4	$168.2	$166.7
O&M Cost/KW Target $ w/o fuel	3.53	1.83	1.43	1.50	1.41	1.20	1.00	0.96
O&M Cost/KW Actual $ w/o fuel	3.68	1.30	1.21	1.34	1.16	1.05	1.02	0.98
O&M Cost/KW Actual $ w/ fuel	4.45	2.03	1.86	1.85	1.67	1.51	1.46	1.43
PEOPLE								
PECO Staff Budget	800	866	914	943	897	892	892	817
PECO Staff Actual	795	824	846	862	874	867	784	796
Total Staff Budget	1,795	1,213	1,150	1,134	1,101	1,037	992	905
Total Staff Actual	1,296	1,147	1,141	1,246	1,088	1,004	896	883
Average Absent Days	N/A	N/A	7.3	8.3	8.5	6.0	7.3	5.5
OSHA Recordables	16	16	24	26	24	10	5	8
OSHA Recordable (Rate)	N/A	1.58	2.13	2.49	2.57	1.09	0.58	0.96
Lost Work Day Cases	9	10	15	16	11	6	1	1
Lost Work Day Case (Rate)	N/A	N/A	1.15	2.06	1.20	0.67	0.12	0.12
LER's	75	57	47	31	28	24	21	29
Coll. Rad Exposure-manrem (Bud)	225	270	160	330	245	265	275	250
Coll. Rad Exposure-manrem (Proj)	263	175	106	330	217	275	260	233

FIG. 4. Limerick Generating Station data sheet.

APPENDIX I

Nuclear Group Document Hierarchy

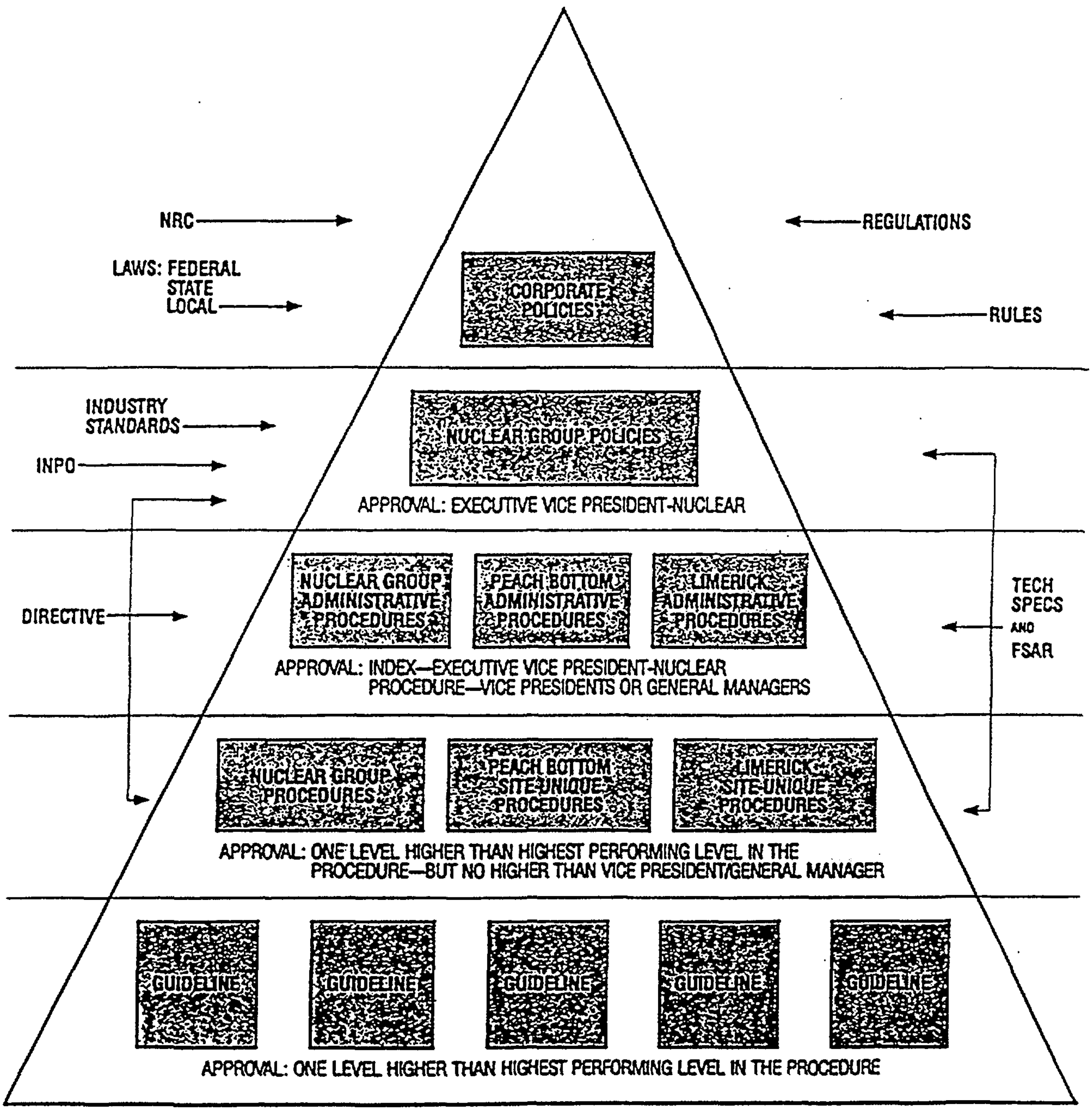


FIG. 5. Nuclear group document hierarchy.

1995 PECO Energy Company NUCLEAR GENERATION GROUP

PECO ENERGY

VISION

To be the best in the Nuclear Generation business.

MISSION

Safely operate our nuclear plants while maximizing our competitive position.

VALUES

Safety, Quality, Competitiveness, Teamwork, People, Integrity

OPERATIONAL OBJECTIVES

SAFETY

All employees take responsibility for nuclear, radiological and industrial safety to create a zero tolerance environment for unsafe personal acts and unnecessary nuclear risks.

ECONOMIC PERFORMANCE

Customers and investors select PECO Energy Company as a result of our reliable and cost effective nuclear operation.

INVESTMENT PROTECTION

Nuclear Generation Group decisions for maintaining operational excellence are based on the optimization of the projected life while minimizing capital and expenses.

REGULATORY PERFORMANCE

Regulatory agencies acknowledge us as the best based on high levels of operational excellence.

INTERNAL AND EXTERNAL RELATIONS

Nuclear Generation Group employees cultivate mutually beneficial relationships characterized by open, direct communications and actions that champion nuclear power.

ORGANIZATIONAL EFFECTIVENESS

The Nuclear Generation Group is a highly effective work team with versatile, self-motivated employees committed to clear management expectations and holding themselves accountable for continuous improvement.

STRATEGIC OBJECTIVES

KEY STRATEGIC OBJECTIVE
ECONOMIC PERFORMANCE

Optimize long-term financial viability through an integrated process to strategically contain and manage operating costs and capital investment, while enhancing safety, performance, productivity and shareholder value.

CAPACITY INCREASES

Define program and develop goals for Capacity Increases beyond those achieved by Power Rerate and Thermal Performance Program (MWe Recovery and Performance Optimization).

INFORMATION TECHNOLOGY

Exploit Information Technology (IT) to enable high payback applications and to increase the Nuclear Generation Group's overall effectiveness through the use of IT.

LIFE CYCLE MANAGEMENT

Define, develop and implement programs and processes to meet Maintenance Rule (10CFR50.65) requirements and position us for evaluating plant license renewal.

PERSONNEL MANAGEMENT

Move towards a high performance organization by implementing an effective performance management system in order to support continued performance standard improvements in the Management, Professional, and Supervisory workforces.

WASTE MANAGEMENT

Design and implement an integrated waste management program to systematically address generating, handling, processing, packing, storing, transporting and disposing of radioactive and chemically hazardous materials.

D.M. Smith *Senior Vice President & CNO* Nuclear Generation Group	D. R. Helwig *Vice President* Limerick Generating Station	G. R. Rainey *Vice President* Peach Bottom Atomic Power Station	W. H. Smith, III *Vice President* Station Support	J. B. Cotton *Director* Nuclear Quality Assurance	J. Doering, Jr. *Chairman, Nuclear Rev. Brd.* Director, Nuclear Strat. Sup.

FIG. 6. 1995 PECO Nuclear posters — PECO Nuclear.

LIMERICK GENERATING STATION

1995 MISSION, OPERATIONAL OBJECTIVES AND GOALS

PECO ENERGY

MISSION

We will generate electricity safely, reliably and efficiently in compliance with federal, state and local regulatory requirements, applicable industry technical standards, quality assurance requirements, and company policies.

1 SAFETY

A Reduce the departmental OSHA recordable incident rate to 1.0 or less.

B Reduce the lost work day incident rate to 0.5 or less.

C Control station collective radiation exposure to achieve less than 215 manrem.

D Limit unplanned automatic SCRAMS per 7000 hours critical to no more than one per unit.

2 ECONOMIC PERFORMANCE

A Manage the O&M & capital expenditures to be less than or equal to the 1995 approved budgets.

B Develop the final 1996 business plans by October 31, 1995.

C Complete the Unit 2 refueling outage on time, as measured against the final, approved outage schedule.

D Maintain the unit capability factor for Unit 1 at or above 88%.

E Maintain the unit capability factor for Unit 2 at or above 78%.

F Perform at least 25% of non-outage modification work with station staff.

3 INVESTMENT PROTECTION

A Complete over 50% of non-outage corrective, maintenance work orders in less than 90 days.

B Maintain an average chemistry performance index of less than 0.25 for each unit during operation.

C Ship no more than 6600 cubic feet of radwaste to site storage pad.

D Implement Performance Monitoring Program improvements identified in 1994 by December 31, 1995.

4 REGULATORY PERFORMANCE

A Conduct at least one self-initiated information exchange meeting with the NRC.

B Implement NEI emergency action levels within six months of approval by the NRC.

C Analyze and learn from unusual plant events so that there are no repeat Level 1 or Level 2 events as defined in Common Nuclear Procedure CNP-LR-C-10.

D Maintain a 90% or better success rate in the annual requalification exams for licensed personnel and achieve a satisfactory NRC licensed requalification program evaluation.

E Implement 90% of the high and medium priority regulatory burden reduction opportunities identified in 1994 by December 31, 1995.

5 INTERNAL AND EXTERNAL RELATIONS

A Station section managers will meet face-to-face with their PBAPS and Station Support counterparts six times per year.

B Provide recognition of personnel involvement in community activities.

C Conduct the annual Emergency Preparedness exercise with no violations and no weaknesses.

D Develop and implement 1995 Internal/External Communications Plan.

6 ORGANIZATIONAL EFFECTIVENESS

A Complete a station-wide self-assessment by November 1, 1995.

B Conduct annual performance appraisals and interim evaluations for all assigned personnel.

C Complete the remaining NEEDS quality transition activities by December 31, 1995.

D Improve effectiveness and performance while implementing VRIP/VSIP transition plans.

E Implement an enhanced common performance appraisal system for all CTAC employees.

F Complete 100% of the Common Nuclear Procedures Program by December 31, 1995.

G Continue to use Quality Management initiatives in accordance with approved plans.

H Conduct two Vice Presidential all-hands meetings.

D. R. Helwig *Vice President*	R. W. Boyce *Plant Manager*	J. A. Muntz *Director* Site Engineering	E. F. Sproat, III *Director* Maintenance
W. G. MacFarland *Director* Outage Management	C. L. Adams *Director* Site Support Services	L. A. Hopkins *Director* Training	W. A. Schwartz *Manager* Human Resources

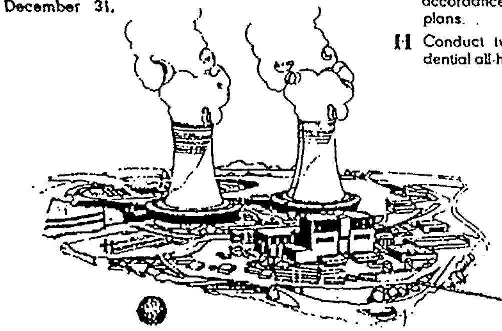


FIG. 7. 1995 PECO Nuclear posters — Limerick Generating Station.

STATION SUPPORT

1995 Mission, Operational Objectives and Goals

PECO ENERGY

MISSION

To provide timely, cost effective quality support for the Nuclear Generation Group and help our customers gain competitive advantage in the generation of electrical power.

1 SAFETY

A Reduce the departmental OSHA recordable incident rate to 1.6 or less.

B Reduce the lost work day incident rate to 0.8 or less.

C Control Nuclear Maintenance Division's radiation exposure to achieve less than 75 manrem.

D Complete two or more processes to improve nuclear safety, including IPEEE and fuel reliability.

2 ECONOMIC PERFORMANCE

A Manage the O&M & capital expenditures to be less than or equal to the 1995 approved budgets.

B Develop the final 1996 business plans by October 31, 1995.

C Complete the Turbine/Generator and Reactor work on time during the PBAPS and LGS refueling outages as measured against the final, approved outage schedules.

D Reduce the number of contract programmers employed by NISD to zero by June 30, 1995.

3 INVESTMENT PROTECTION

A Maintain mod schedules to meet 100% of all agreed upon Rev. 0 dates.

B Install 3D Monicore on all four units utilizing NISD resources in accordance with the Fuel and Services schedule.

C Complete the Rev. 0 approval of DBD's by July 31, 1995.

D Perform all MOD Conceptual Designs within 30 days.

4 REGULATORY PERFORMANCE

A Conduct at least six self-initiated information exchange meetings with the NRC resident/regional inspectors.

B Implement NEI emergency action levels within six months of approval by the NRC.

C Analyze and learn from unusual plant events so that there are no repeat Level 1 or Level 2 events as defined in Common Nuclear Procedure CNP-LR-C-10.

D Attain 0% overdue external commitments to regulatory agencies.

E Implement NEI developed commitment change process within three months of NRC approval.

F Initiate the USFAR reduction process within three months of NRC approval.

5 INTERNAL AND EXTERNAL RELATIONS

A Station Support managers will meet face-to-face with their site counterparts six times per year.

B Provide recognition of personnel involvement in community activities.

C Support conduct of the annual Emergency Preparedness exercises for LGS and PBAPS with no violations and weaknesses.

D Develop and implement 1995 Internal/External Communications Plan.

E Complete simulator core model upgrade for Peach Bottom training by December 31, 1995.

6 ORGANIZATIONAL EFFECTIVENESS

A Complete the Station Support self-assessments by July 1, 1995.

B Conduct annual performance appraisals and interim evaluations for all assigned personnel.

C Complete the remaining NEEDS quality transition activities by December 31, 1995.

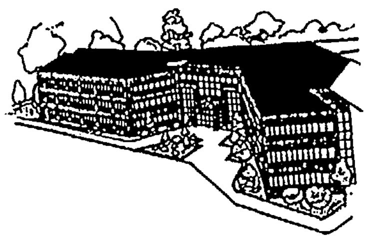
D Improve effectiveness and performance while implementing VRIP/VSIP transition plans.

E Implement an enhanced common performance appraisal system for all CTAC employees.

F Complete 100% of the Common Nuclear Procedures Program by December 31, 1995.

G Continue to use Quality Management initiatives in accordance with approved plans.

H Conduct two Vice Presidential all-hands meetings.



W. H. Smith, III, Vice President | D. B. Fetters, Director, Engineering | J. W. Austin, Director, Nuclear Maintenance | G. C. Bell, Director, Labs | C. J. Olenik, Interim Director, Nuclear Information Systems | G. A. Hunger, Director, Licensing | H. J. Diamond, Director, Fuel & Services | A. S. MacAinsh, Manager, Support Services

FIG. 8. 1995 PECO Nuclear posters — station support.

NUCLEAR QUALITY ASSURANCE

1995 Mission, Operational Objectives and Goals

PECO ENERGY

MISSION

We will continually strive to improve the QUALITY of Nuclear Generation Group operations, seeking cost effective ways to achieve customer satisfaction and to pursue the PECO Energy Company Vision.

1 SAFETY

A Reduce the departmental OSHA recordable incident rate to 1.0 or less.

B Maintain lost work day incident rate of 0.

C Control NQA collective radiation exposure to achieve less than 11.1 man-rem.

D Sponsor at least two integrated assessments of major mods from conceptual design to installation and test.

2 ECONOMIC PERFORMANCE

A Manage the O&M expenditures to be less than or equal to the 1995 approved budget.

B Develop the final 1996 business plans by October 31, 1995.

3 INVESTMENT PROTECTION

A Establish resource book for various computer programs used by NQA personnel.

B Augment the Vendor Improvement Plan to include Commercial Grade Item and Dedication Process Vendors.

4 REGULATORY PERFORMANCE

A Conduct quarterly information exchanges between the NRC residents and the Quality Division and ISEG Mangers at each site.

B Evaluate Tech. Spec. and Regulatory commitments for potential CBLA's and initiate changes.

5 INTERNAL AND EXTERNAL RELATIONS

A NQA managers will meet face-to-face with each station director twice a year.

B Provide recognition of personnel involvement in community activities.

C Send NQA representatives or vendors to four plants to obtain ideas for improvement for NQA and Station activities.

6 ORGANIZATIONAL EFFECTIVENESS

A Complete a department-wide self-assessment by December 31, 1995.

B Conduct annual performance appraisals and interim evaluations for all assigned personnel.

C Complete the remaining NEEDS quality transition activities by December 31, 1995.

D Improve effectiveness and performance while implementing VRIP/VSIP transition plans.

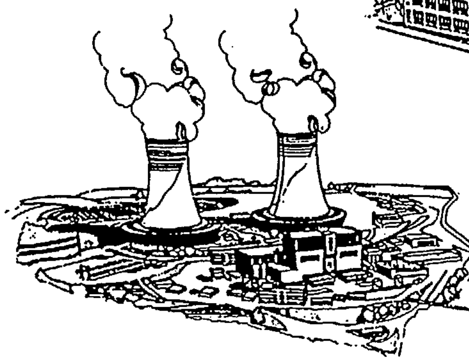
E Implement an enhanced common performance appraisal system for all CTAC employees.

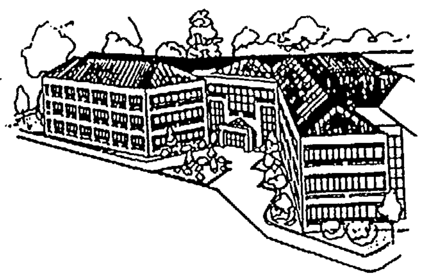
F Complete 100% of the Common Nuclear Procedures Program by December 31, 1995.

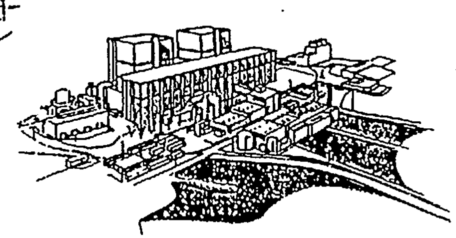
G Continue NQA Quality Management in accordance with approved plans.

H Re-engineer the NQA function.

I Implement assessment process improvements in accordance with approved plans.







J. B. Cotton	W. A. Texter	A. A. Fulvio	C. A. Mengers	F. W. Polaski	J. G. Hufnagel
Director	Manager	Manager	Manager	Manager	Manager
	Site QA—Chesterbrook	Site QA-Peach Bottom	Site QA—Limerick	ISEG—Peach Bottom	ISEG—Limerick

FIG. 9. 1995 PECO Nuclear poster — NQA.

LGS
O & M COST SUMMARY

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	1991	1992	1993	1994	1995	1996
OFFICE OF VP	($1,729,000)	$829,016	$835,537	$326,000	($59,155)	$278,000
SITE SUPPORT SVCS.	$22,395,000	$22,288,630	$22,207,090	$24,681,000	$24,317,075	$22,531,000
TRAINING	$5,541,000	$5,000,652	$4,763,152	$3,881,000	$3,941,606	$3,904,000
OUTAGE MGMT.	$5,144,000	$5,044,037	$5,595,505	$18,337,000	$19,546,617	$21,675,000
HUMAN RESOURCES	$0	$260,003	$409,378	$269,000	$358,297	$238,000
PLANT MGMT.	$30,791,000	$33,401,889	$35,497,816	$32,183,000	$29,827,065	$27,337,000
STATION ENGINEERING	$5,532,000	$4,991,137	$8,003,365	$8,410,000	$8,516,649	$8,228,000
MAINTENANCE	$46,287,000	$49,323,758	$42,604,788	$28,208,000	$29,184,551	$27,434,000
TOTAL	$113,961,000	$121,139,122	$119,916,631	$116,295,000	$115,632,705	$111,625,000

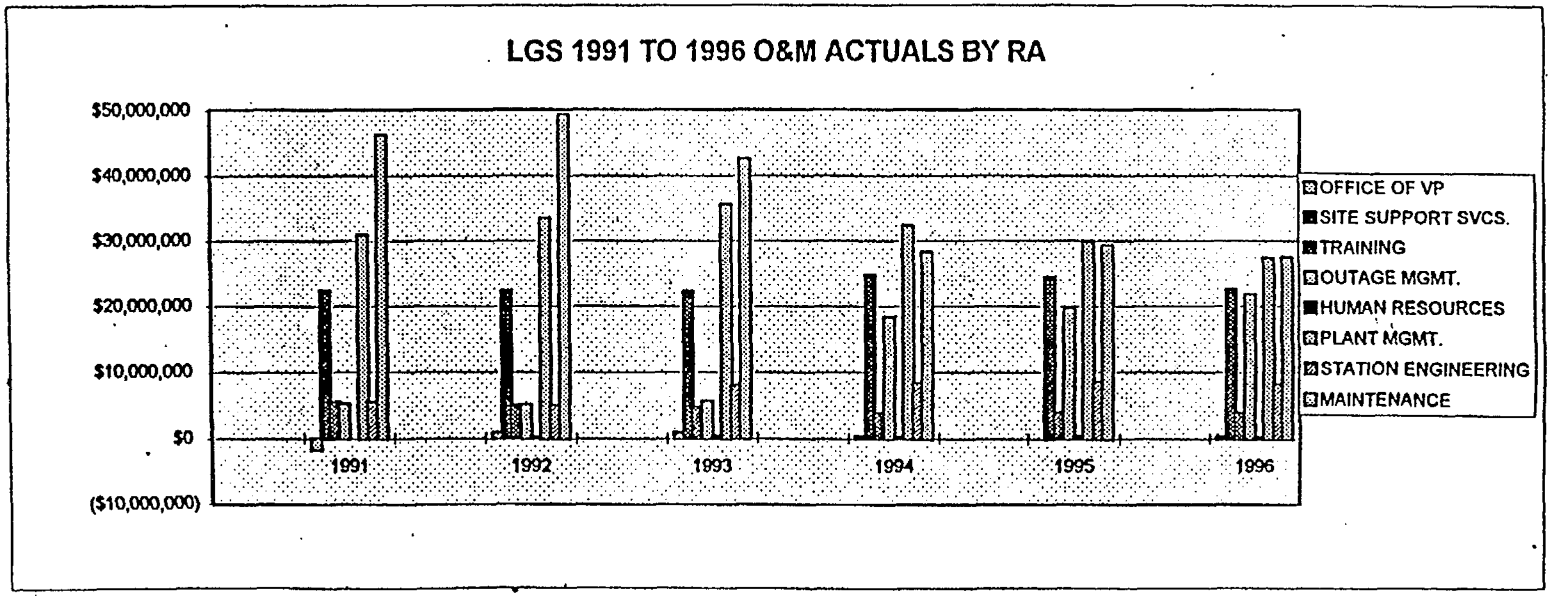

FIG. 10. Limerick Generating Station O&M cost summar.

LGS
O & M COST SUMMARY
ANNUAL HIGHLIGHTS

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1991 BUDGET - $115.6M — VARIANCE - $1.6M UNDER

- REFUELING OUTAGE
  - 2RO1 - $0.90M UNDER BUDGET (74 DAYS)
- OFFICE OF V.P. - MATERIAL MARKUP ADJUSTMENTS
- HUMAN RESOURCES INCLUDED WITH SUPPORT SERVICES

1992 BUDGET - $114.5M — VARIANCE - $6.6M OVER

- REFUELING OUTAGE
  - 1RO4 - $6.3M OVER (111 DAYS)
  - EXCEEDED SCHEDULE BY 41 DAYS DUE TO SCOPE ADDITIONS & EMERGENT WORK

1993 BUDGET - $118.7M — VARIANCE - $1.8M OVER

- NEEDS - EXTERNAL TRANSFERS FROM CHESTERBROOK (PARTICULARLY TO STATION ENGINEERING)

1994 BUDGET - $120.3M — VARIANCE - $4.0M UNDER

- PECO LABOR - VSIP/VRIP
- DEFERRAL OF 2RO3 MATERIAL EXPENSES TO JANUARY, 1995
- REDUCTION IN SECURITY FORCE

1995 BUDGET - $116.6M — VARIANCE - $0.96M UNDER

- PECO LABOR - VSIP/VRIP
- EXPENSE MODIFICATION UNDERRUN

1996 BUDGET - $112.5M — VARIANCE - $0.89M UNDER

- REFUELING OUTAGE
  - 1RO6 - DELAYED START DUE TO COLD WEATHER CONDITIONS
- EXPENSE MODIFICATION UNDERRUN
- WATER DIVERSION AND POINT PLEASANT PAYBACK UNDERRUNS DUE TO LOWER OPERATING EXPENSES

FIG. 11. Limerick Generating Station O&M cost summary — annual highlights.

PECo NUCLEAR GROUP VISION AREAS

TECHNICAL	COMPETITIVE	POLITICAL	CULTURAL
• INPO Rating 2 or above • 3-year average capacity factors in top quartile • NRC SALP Rating 1.3 or better • Modifications reflect high priority for long-term radiation exposure reduction	• Cost of generation in lowest quartile of all U.S. nuclear units • Expenditures reflect strategic planning needs of company • Capital expenditures reflect Nuclear Group objectives	• Nuclear Group well respected as a team player in corporate organization • Consistently viewed by industry as highly respected "nuclear utility" • Nuclear successes are such that company is not forced to use political processes to resolve issues with external stakeholders • Governmental agencies maintain positive or neutral perceptions regarding Nuclear Group operations	• High commitment/high performance work culture dedicated to continuous improvement • Strong internal teamwork • Planning, planning and more planning • Development of and reliance upon PE expertise which includes a strong understanding of external issues • Systems in place for internal development of high quality supervisors and managers • Quality control is integral with various organizations, not a separate entity

FIG. 12. World class performance definition.

An agreement was signed in 1927 by Public Service Electric and Gas Company of New Jersey (PS, Newark), Pennsylvania Power & Light Company, (PL, Allentown), and Philadelphia Electric Company (PE), creating the Pennsylvania-New Jersey Interconnection. The purpose of the agreement was to take advantage of the predictable diversity between peaks unique to each company and to provide for the exchange of economy power. This system also provided for the best use of hydroelectric energy from Conowingo (PE), Holtwood (PL) and, later PL's share of Safe Harbor (PL and Baltimore). This was the first interconnection to utilize high voltage (220,000 volts) transmission to exchange power. To implement the agreement a high voltage "ring" of transmission lines was built to connect the three systems. The carrying charges of the transmission lines were shared among the companies.

Subsequently, the load of the General Public Utilities Corporation (GPU) was included with PS, the electric load of UGI in the Scranton-Wilkes Barre area (Luzerne Electric Division of UGI Corporation) was included with PL, and the loads of Atlantic City Electric Company (now Atlantic Electric, ACE) and Delaware Power & Light Company (now Delmarva, DPL) were included with PE.

In 1956, a new agreement was signed in which the three original members, PS, PL, and PE, were joined by GPU and Baltimore Gas and Electric Company (BC). This was designated as the Pennsylvania-New Jersey-Maryland Interconnection (PJM). At that time the Washington, DC, load was included as a part of the Baltimore load. In 1965, the Potomac Electric Power Company (PEPCO), supplying the metropolitan Washington, DC, area became a signatory member, making a total of six members with three associates (UGI, ACE, and DPL). On June 1, 1981, ACE and DPL became full members of PJM.

The PJM companies in 1968 formed the Mid-Atlantic Area Council (MAAC), which became a member of the National Electric Reliability Council (NERC) when it was created the following year. There are eight other councils in NERC, representing all segments of the electric industry (private and public) in the United Sates and parts of Canada.

Operation of the PJM Control Area involves activities that are performed by different operating and technical personnel. These activities occur in parallel on a continuous basis and can be grouped into three overlapping time frames: (1) pre-scheduling operations, (2) scheduling operations, and (3) dispatching operations. Dispatching includes system control, Ancillary Service monitoring, and transmission system monitoring and control. During the dispatching process, the PJM IA (Interconnection Association) implements and adjusts the Current Operating Plan, which is developed during the scheduling process, to maintain reliability and minimize the cost of supplying the energy, reserves, and other services that are required by the Market Participants and the operation of the PJM Control Area.

The PJM IA scheduling philosophy is to schedule generation that results in the least-priced generation mix, while maintaining the reliability of the PJM Control Area. The scheduling process evaluates the price of each available generating unit compared with every other available generating unit. The philosophy for scheduling the PJM Control Area requires:

- scheduling sufficient generation to cover PJM Control Area load and Operating Reserve requirements
- ensuring Market Participants participate in the analysis and elimination of conditions that threaten the reliable operation of the PJM Control Area

Scheduling of generation resources by the PJM IA is performed economically on the basis of the prices and operating characteristics offered by the Market Sellers, using secure, constrained dispatch and continuing until sufficient generation is dispatched in each hour to serve all energy purchase and PJM Control Area requirements.

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Consultants Meeting

Vienna, Austria, 6–7 December 1995
17–21 February 1997
6–8 October 1998

Specialists Meeting

Vienna, Austria, 30 September–2 October 1996

Advisory Group Meeting

Vienna, Austria, 3–6 June 1997