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Guidebook on training to establish and maintain the qualification and competence of nuclear power plant operations personnel

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FOREWORD

There is worldwide interest in improving the safety and reliability of nuclear power plants, which to a high degree depend on the competence of their personnel. To maintain and enhance the competence of nuclear power plant operations personnel, it is essential that they acquire and maintain fundamental knowledge and practical skills through relevant, practical-oriented education and training, through adequate on-the-job training, and through continuing training.

In nuclear power there can be no compromise with safety, and high quality standards must be established and strictly maintained. This can be achieved only with thoroughly qualified staff. Although there are various ways of achieving the required level of competence for operations personnel, the same level must be attained in every country which operates a nuclear power plant.

The operating organization is responsible for the training of operations personnel in order to establish and maintain their qualifications and competence required for their jobs. Programmes are established for training and retraining operating and maintenance personnel to enable them to perform their tasks and functions safely and efficiently. Training is particularly intensive for control room staff and emphasizes the use of simulators.

Since the IAEA published its Guidebook on the Qualification of Nuclear Power Plant Operations Personnel in 1984 (Technical Reports Series 242) there have been important developments in the approach to training adopted by many operating organizations in different countries. It is now accepted that developing training programmes based solely on experience is inappropriate for the nuclear power industry, and that a systematic approach to training is necessary. It has been recognized that inadequate knowledge and skills may lead to human errors, and it is therefore necessary to review and improve the development and implementation of initial and continuing training programmes. The present Guidebook proposes an approach which is comprehensive and systematic in its methodology and also cost effective in its implementation.

This Guidebook is mainly intended for management and training staff of nuclear power plant operating organizations. Relevant examples of current training practices are presented in the Appendices, which constitute an integral part of the Guidebook.

Appreciation is expressed for their valuable contributions to all those who participated in the preparation of this Guidebook and also to the Member States for their generous support in providing information and experts to assist the IAEA in this work.

EDITORIAL NOTE

CONTENTS

NOTE

This revised version of IAEA-TECDOC-525 reproduces only the main text (Chapters 1–6) of the original document published in 1989, i.e. without the appendices. However, since the main text is printed here without change, references to the appendices have not been omitted.

Chapter 1

INTRODUCTION

1.1. THE IMPORTANCE OF TRAINING FOR NUCLEAR POWER PLANT SAFETY AND RELIABILITY

Since the IAEA published its Guidebook on the Qualification of Nuclear Power Plant Operations Personnel in 1984 (Ref. [1]) there have been important developments in the approach to training adopted by many operating organizations in many countries.

These organizations have recognised the continuing impact which inadequate knowledge and skills have on those incidents in which the human factor is a root cause (Ref. [2]) and have taken the initiative to review and improve the development and implementation of their initial and continuing training programmes. This Guidebook presents an approach which is not only comprehensive and systematic in its methodology but also cost-effective in its implementation.

The importance of effective training in ensuring nuclear plant safety and reliability cannot be overestimated. The IAEA's International Safety Advisory Group, in its 1988 Report (see Ref. [3] and Appendix A) included among the basic safety principles for nuclear power plants the following:

- One of the most important lessons of abnormal events, ranging from minor incidents to serious accidents, is that they have so often been the result of incorrect human actions.

- The operating organization must recognize the high technology aspect of nuclear power plants and must ensure that its staff is able to manage it satisfactorily.

- The human error component of events and accidents has been too great in the past. The remedy is a twofold attack, through design, including automation, and through optimal use of human ingenuity in unusual circumstances.

- The operating organization is responsible for providing all equipment, staff, procedures and management practices necessary for safe operation, including the fostering of an environment in which safety is seen as a vital factor and a matter of personal accountability for all staff.

- It may seem on occasion that emphasis on safety might be in conflict with the requirement to achieve a high capacity factor and to meet all demands of electricity generation. This conflict is more apparent than real, and it can at most be transitory, in that the factors of design, construction and operational management that promote safety generally coincide with those that contribute to reliability in operation. Reliability in the long term is not served by compromising safety in the short term.

- Training of maintenance staff goes beyond the teaching of basic task skills to emphasize the potential safety consequences of technical or procedural error. Training and qualification of maintenance staff reflects the realization that where there has been a record of plant operational unreliability and faulty, spurious and accidental activation of safety systems in the past, it has often been caused by errors in maintenance procedures and practices. Training of maintenance staff covers such incidents. Testing of maintenance staff examines their familiarity with these lessons.

Several studies of accidents and incidents that have occurred at nuclear power plants have shown that human error has been a large contributing factor to those incidents and that inadequate training or knowledge of the personnel has contributed to those human errors (see Appendix B). A highly competent operating and maintenance staff is a most important component in the "defense in depth" strategy for ensuring nuclear power plant safety and protection of the public.

Because the responsibility for plant safety and for the competence of plant personnel rests with operating organizations, this Guidebook is aimed at the management and training staff in those organizations. It is intended for both developing countries and those with well-established nuclear power programmes. The adoption of a systematic approach to training and qualification as described in this Guidebook is strongly recommended for all operating organizations, based on the experience and judgement of those who have implemented or are implementing such an approach and have obtained the benefits that it can produce.

1.2. ROLE OF QUALIFIED PERSONNEL IN NUCLEAR POWER SAFETY

Qualification and training of nuclear power plant personnel is of vital importance for nuclear power safety, and substantial efforts should be expended for their establishment and continuing upgrading. There is worldwide interest in improving the safety and reliability of nuclear power plants, which to a high degree depend on the competence of their personnel.

For a country about to embark on or in the process of implementing a nuclear power programme, the lack of qualified personnel with competence to perform the key tasks and functions of nuclear power plant operation and maintenance is one of the major problems and constraints. The special problems facing a country introducing nuclear power for the first time are described in Chapter 5. The main responsibility of the nuclear power operating organization is to ensure the safe and reliable operation of the nuclear power plant, and this responsibility must be borne by the operating organization, whether it is a utility, nuclear energy authority or other body. Thus, each country must initiate and implement an effective policy and programme for training nuclear power project personnel to meet its responsibility and objective for ensuring the safety and reliability of its nuclear power operations.

Qualified and competent personnel play an essential role in preventing nuclear incidents and accidents and in handling them correctly if they do occur. The required qualifications and competence can only be achieved through appropriate education, training and experience. In nuclear power there can be no compromise with safety; high safety and quality standards must be established and strictly maintained, and this can be achieved only with thoroughly qualified staff. Although there are various ways of achieving the required level of qualifications and competence for operations personnel, the same level must be attained in every country which operates a nuclear power plant.

In practically every phase and activity of a nuclear power programme, advanced technology is involved, which requires qualified personnel capable of understanding, adapting, and applying the technology. In a country without a nuclear industry, technology is usually acquired from a more advanced country able and willing to transfer it. However, for technology transfer to be successful, the recipient country must be capable of absorbing the technology; the key to this, again, is the availability of qualified manpower.

It is essential that operations personnel develop and maintain fundamental knowledge and practical skills through relevant, practical-oriented education and training, through adequate on-the-job training, and through continuing training. Some countries have had problems in providing sufficient practical training and experience for the professional engineers (university-level graduate engineers - see Fig. 3.2.-1) and high-level technicians needed for nuclear power plant operations.

It is important to note that the cost of education and training which will produce the necessary qualified personnel amounts to a very small fraction of the cost of a nuclear power project. Further, the costs of the education and training of the personnel for a nuclear power project are extremely small when compared with the economic, financial and other costs incurred if a nuclear power plant has to be taken out of operation, even for a short time, because of incorrect actions on the part of insufficiently competent and qualified personnel.

Thus, good education and training are not only necessary but also a sound investment in the safe and economic operation of nuclear power plants. For this reason, provision of education and training, including continuing training, should be an integral part of nuclear power operations.

All of these represent important tasks and problems to be dealt with in the process of establishing and maintaining the competence and qualifications of nuclear power plant operations personnel. To meet these challenges and requirements successfully will require the resources, efforts, and cooperation of government, utilities, industry and the relevant education, training and research institutions in a country.

1.3. RECOMMENDED AREAS FOR IMPROVEMENT IN INITIAL AND CONTINUING TRAINING

Key concepts and requirements which characterize the nature and aims of successful nuclear power plant operations are: responsibility, quality and competence throughout the entire organization and in the performance of each and every task and function. Responsibility, quality and competence in job performance are needed especially for those dealing with the operating and maintenance functions of the plant, and with the management, training and continuing training of operating and maintenance personnel.

OSART missions have identified several training-related weaknesses, including: inadequate training and continuing training of operations and other plant personnel; inadequate following of and emphasis on established procedures; insufficient "safety culture" or safety awareness; personnel overconfidence in their knowledge of the plant and in their abilities to control it; man-machine interface problems; and deficiencies in management, organization, and operations procedures (see Reference 2).

Related to these problems, it has been observed that managers and supervisors often do not sufficiently motivate or control personnel nor are they sufficiently involved in training and qualification to ensure that high performance standards are achieved and maintained, and that personnel adhere to established procedures.

Some of the recurring problems in the development, qualification and evaluation of personnel and in the associated training programmes have resulted in the following recommendations:

- Training programmes should include all important topics, including quality assurance principles, plant administrative procedures, response to accidents progressing beyond the design basis; stress management; diagnostics; team training; and operating experience.
- Plant-specific lists of tasks should be maintained complete and up-to-date.
- Learning objectives should provide measurable requirements and standards for evaluating trainee performance.
- Programmes should have detailed lesson plans setting out learning objectives and written procedures on how to conduct training, to assure consistent quality of training.
- Training methods and materials should be appropriate for learning objectives.
- Sufficient details of specific significant events (root causes of event, lessons learned, applications to the plant) should be included in training.
- On-the-job training should be adequately controlled and evaluated.
- Guidelines and qualification checklists should be used to ensure uniformity of on-the-job-training.
- Supervisors and managers should receive adequate training in leadership, communications, stress management, motivation, supervisory and related skills.
- Standards for trainee performance during simulator training should be specific and should provide a basis for meaningful assessment of individual and team performance.
- Incumbents should be assessed in terms of performance-based training requirements, so that the personnel qualifications and training needs of incumbents are clearly determined.
- Post-training feedback should be formally gathered and used to improve training.
- Instructors should maintain and improve their technical knowledge and skills.
- Incumbents should be assigned independent work only after receiving required training and being qualified for the job.
- Continuing training should include areas of observed performance deficiencies, plant or procedure changes, and infrequently performed but difficult and important tasks.
- Continuing training should be recognized as an essential part of operations activities.
- Training programs should include periodic drills to ensure that the personnel can respond to emergencies (for example, shutdown of the plant if the control room cannot be occupied).

1.4. SYSTEMATIC APPROACH TO TRAINING

A systematic approach to training (SAT) such as that described in this Guidebook offers significant advantages in consistency, efficiency, cost-effectiveness, management control, and accountability in the training and qualification of operating and maintenance personnel. SAT also incorporates the flexibility to adapt to new trends for improvements in the human component of plant operations, e.g., the trend towards the development and implementation of symptom-based procedures. SAT provides for management monitoring of and responsibility for personnel performance at all levels, including personnel performance evaluations to ensure that staff are adequately qualified.

Systematic approaches to training involve performance-based and task-based training which, when used correctly, can establish and maintain the competence and qualifications of operations personnel. Such a training programme should be defined and implemented for each group of personnel. The main elements and activities of SAT include:

- Defining competence requirements: using training needs analysis, job analysis and task analysis

- Designing a training programme: establishing trainee performance standards and developing learning objectives

- Developing a training programme: developing lesson plans; specifying training activities; developing materials

- Implementing a training programme: conducting training and assessing trainee performance

- Evaluating and improving a training programme

Many of the best training programmes are based on learning objectives derived from a job and task analysis, and they are improved continually - for instance, by soliciting feedback from ex-trainees and supervisors. The best programmes also take into account operating experience not only from the plant itself but from other plants, and they include training for response to severe accident conditions.

Training materials such as simplified system descriptions and flow diagrams (process and instrument diagrams) should be provided to ensure comprehension of the plant and system functions. As far as possible, training materials and facilities should represent actual plant conditions. Initial and continuing simulator-based training for the control room shift team personnel should be conducted on a simulator which replicates the power plant control room desk and panels and has software of sufficient scope to cover a full range of normal, abnormal and emergency operating scenarios. The effectiveness of classroom instruction should be enhanced by use of visual aids such as video tapes, films, slides and viewgraphs to demonstrate actual plant conditions.

The job-specific training and qualification programme for each personnel group should develop and improve the knowledge and skills necessary to perform the assigned tasks and functions under all conditions. Training programmes for supervisors and managers should be designed to develop their supervisory and management skills as well. Control room supervisory personnel should be trained in stress management and in relevant behavioural sciences. In addition, they should be provided with supervisory, leadership and communication training.

A systematic approach to continuing training is also essential, in particular for operating and maintainence personnel, in order to maintain and upgrade their levels of qualification and competence. These personnel should undergo formal continuing training on a regular basis, and the time needed for this should be taken into account when work schedules are established. Simulator training exercises for operators should be planned systematically and should reflect operating experience.

Feedback from trainees and supervisors, the results of performance assessments, and operating experience acquired both at the plant itself and from other utilities and industry generally should be drawn upon to improve all these training programmes.

Instructors must be well qualified in their technical and teaching competence. They should be required to keep up-to-date in their own technical and teaching qualifications as well as in their knowledge of the job requirements, plant system changes, current practices and operating procedures.

1.5. ROLE OF PLANT MANAGEMENT IN TRAINING AND QUALIFICATION

Plant managers must ensure that plant personnel are adequately trained and must give sufficient attention to the quality and details of the established plant procedures for which personnel are to be trainied. Some plant managers have underestimated the importance of training all personnel systematically and of establishing and effectively implementing programmes for continuing training.

Plant managers have an especially important role to play in the fulfillment of their responsibility to ensure qualified and competent operations personnel (see also Ref. [4]). Operations management should be involved in defining continuing training needs and ensuring that initial and continuing simulator training reflects operating practices and standards. Operations managers and supervisors should take action to ensure that personnel are trained to adhere to established procedures, and that they do so in practice. The operating organization's management should evaluate the quality of the training provided both in the plant and at any separate training centre(s) utilized for the training of plant personnel. And, finally, senior plant management should foster the proper attitudes of plant personnel towards their work through personal involvement in operations and training activities.

1.6. CONCLUSION

To ensure safety and reliability of nuclear power plant operations, operating organizations should commit adequate resources and management attention to the training and qualification of plant personnel. The competence of these personnel to a great extent determines the success of a nuclear power programme. It is widely accepted that a systematic approach to training, such as the approach that is described in this Guidebook, is the most efficient and effective method of achieving the required personnel competence.

1.7. REFERENCES

[1] Qualification of Nuclear Power Plant Operations Personnel: A Guidebook, Technical Reports Series No. 242, IAEA, Vienna (1984).

[2] The Human Factor Information Feedback in Nuclear Power: Implications of Operating Experience on System Analysis, Design and Operation, Proc. of IAEA-NPPCI Specialists' Meeting in Riso, Denmark, 26-28 May 1987, Riso National Laboratory, Roskilde, Denmark, (1987).

[3] Basic Safety Principles for Nuclear Power Plants: A Report by the International Nuclear Safety Advisory Group, Safety Series No. 75-INSAG-3, IAEA, Vienna (1988).

[4] OSART RESULTS: A Summary of the Results of Operational Safety Review Team Missions During the Period August 1983 to May 1987, IAEA-TECDOC-458 (1988).

Chapter 2

ORGANIZATION AND STAFFING

2.1. INTRODUCTION

The operations personnel in a nuclear power plant should collectively have adequate knowledge and skill to accomplish all the tasks necessary for safe plant operation. As described in Chapter 4, the knowledge and skills required for the jobs and tasks which have to be accomplished can be derived by analysis of the positions' responsibilities and tasks. Therefore, it is necessary that they are clearly defined for each position within the nuclear power plant organization. Such definitions must cover all phases of plant operation (construction, commissioning, normal operation, outages and emergencies) and specify the responsibilities and tasks that are assigned to each incumbent.

The purpose of this Section is to discuss some major characteristics of nuclear power plant organizations, with emphasis on those which affect the training and qualification of plant personnel, the subject of this guidebook. Establishment of the plant organization is a prerequisite for the analysis and determination of the personnel qualifications required for each job. This Section does not attempt to discuss all topics which are important to establishing and managing plant organizations.

2.2. PRINCIPLES OF NUCLEAR POWER PLANT ORGANIZATION

For nuclear power plant operations personnel to carry out their functions effectively requires the existence of a well-designed plant organization in terms of structure and function, which includes the following:

- a well-defined structure of positions, which provides a command and communication system to put the organization to work

- definitions of the functions of each position (the responsibilities, tasks and authority allocated to each position) which together cover all activities necessary to ensure the safe and efficient operation of the plant

- a monitoring system which ensures the activities are directed to the accomplishment of utility objectives and that they are performed as intended and in conformity with utility policy.

It is apparent that the nuclear power plant organization has to be structured for continuous plant operation (i.e., 24-hour shift work for basic operations and required support functions). The operating organization must also be structured to carry out emergency functions and those functions required for major repairs and refueling outages.

2.3. MAJOR FACTORS WHICH AFFECT NUCLEAR POWER PLANT ORGANIZATIONS

Because the basic tasks and problems associated with the operation of all nuclear power plants are similar, many common features can be found in the organizations established in different utilities. However, many differences can be found due to the following:

- Plant technology and design: reactor type, plant output, plant layout, number of components, level of automation, the existence of single or multiple units at a site.

- The extent of utility support to the plant: the existence of headquarters support to the plant in such activities as major maintenance, spare parts supply, fuel procurement, safety and other analyses, commercial and financial matters, etc.

- The impact of organised labour in the country: this can affect both the organisational structure and the specification of training requirements.

- Utility personnel management and staffing policy: the use of some nuclear power plants as manpower sources for future nuclear plants, personnel scheduling practices, and the appointment of additional staff in some key positions to compensate for staff leave, training, and turnover without the need for working extensive overtime.

- The availability of external contractor support to the plant: major maintenance during outages, modifications of systems and components, design, and analytical work.

- Regulatory requirements: activities, functions, or positions required by the licensing authorities (e.g., the use of shift technical advisors in some countries).

2.4. ORGANIZATION AND FUNCTIONS FOR PLANT OPERATION

A well-structured nuclear power plant organization ensures that qualified personnel are in place to perform all functions necessary for safe, reliable, and efficient plant operation. The nuclear power plant organization includes individual positions that collectively cover the whole spectrum of required activities.

In a typical nuclear plant organization, there are positions whose primary duties and assigned tasks involve direct operation of the nuclear power plant and its systems and components. In addition, there are positions needed to support plant operation and other positions that are primarily responsible for monitoring activities to ensure that they are performed as intended and evaluating plant performance to detect problems that should be corrected. In practice, most positions include some combination of these basic functions; for example, many individuals perform both support and monitoring/evaluation functions. Table 2.4.-1 lists and briefly describes the most common functions performed by nuclear power plant personnel. Operations functions generally are understood to include those dealing with direct operation and with maintenance.

The plant functions are assigned to departments or groups, leading to an organisational structure as shown in Figure 2.4.-1.

It is normal practice that the managers responsible for monitoring and evaluation functions do not report to managers in charge of the operating and support functions which they monitor and evaluate. This can be accomplished by appointing a deputy plant manager (sometimes called the operations or production manager) to manage the power production activities and allow the

TABLE 2.4.-1. PRINCIPAL FUNCTIONS FOR NUCLEAR POWER PLANT PERSONNEL

Direct Operation

The direct operation function includes all positions necessary to operate the plant as a whole, including the operation of individual plant systems in accordance with plant manuals (normal, abnormal and emergency procedures, technical specifications, Final Safety Analysis Report and licensing requirements). It may also include refueling operations together with associated plant operations which ensure subcriticality is maintained, residual heat is removed and the release of radioactivity is prevented.

Reactor Physics

Calculate, measure, and evaluate nuclear and thermodynamic parameters of the reactor core (reactivity, reactivity coefficients, control rod worth, etc.), interpret plant data, and predict fuel burn-up.

Fuel Management

Specify control rod withdrawal sequences, refueling schemes, and refueling procedures, and assist the operating crew during refueling (sometimes combined with the reactor physics function).

Fuel Handling

Effect all fuel movement, i.e., receive and store new fuel; transfer fuel to, from and within the core; and transfer irradiated fuel to the spent fuel storage facility.

Radioactive Waste Management

Operate all facilities for treatment, storage, and shipment of liquid and solid radioactive waste generated at the site.

Mechanical Maintenance

Perform preventive maintenance, repairs, and modifications of mechanical systems and components.

Electrical Maintenance; Instrumentation and Control (I&C) Maintenance

Perform preventive maintenance, repairs, and modifications of electrical and I&C systems and components (sometimes these functions are separated into electrical and I&C.).

Planning and Scheduling

Plan and schedule all activities related to the operation of the plant (it is especially important to plan in detail the activities for outages).

Quality Assurance (QA)

Monitor the implementation of all plant activities as described in plant QA plan, conduct audits and provide feedback to plant management.

Performance Analysis and Review

Monitor, analyze, and review the nuclear safety and operational performance of each plant component and system and of the overall plant.

In-Service Inspection

Periodically monitor the integrity of primary plant components (reactor vessel, pressurizer, piping, steam generator tubing) and selected secondary plant components (condenser tubing, reheaters); compare results with base-line data established in pre-service inspection.

Health Physics (HP) (or Radiological Protection - RP)

Measure and evaluate radioactivity levels on- and off-site, and the radiation doses received by personnel; keep records of individual and collective doses received; advise management on radiological protection requirements, devices, techniques and procedures; assist in preparation and conduct of emergency planning.

Medical

Arrange for periodic medical checks (and any psychological tests) on the health and fitness of the nuclear power plant staff; provide a first aid service at the plant.

Chemistry

Make all necessary chemical (including radiochemical) analyses related to the operation of the plant; monitor corrosion in sensitive components (e.g. steam generator and condenser tubes); analyze corrosion deposits in plant components; advise on the operational mode to minimize corrosion effects on plant components and to prevent the creation of radioactive particles.

Fire Fighting

Fight fires on-site; maintain fire-fighting equipment, clothing, etc.; perform exercises and drills; coordinate the activities with off-site fire-fighting brigades.

Industrial Safety

Establish and implement rules for employee protection (excluding radiological protection) during on-site activities.

Security

Control access of personnel and potentially dangerous and/or undesirable articles and equipment to the site and to specified parts of the plant.

Spare Parts Management

Manage the procurement of spare parts necessary for the continuous operation of the plant.

TABLE 2.4.-1. (continued)

Evaluation of Operations Experience

Monitor and evaluate operations experience at the plant and incident reports from other plants; consult off-site expert groups; inform the licensing authorities in accordance with established rules; modify the operating procedures based on the results of evaluations; contribute to the identification of required additional training if appropriate.

Training

Develop and maintain the competence of all nuclear power plant staff by planning, developing, conducting and evaluating appropriate training using the training staff and experts from other plant departments and off-site organizations.

Document Control

File, control, and maintain plant technical documents (drawings, procedures, manuals, reports); maintain current revisions; provide easy access to and retrieval of stored documents; continuously update operating manual.

Emergency Planning and Public Information

Prepare plans and conduct training for response to plant emergencies; provide information to and maintain relations with the media, government agencies, and the general public.

Administration

Organize administrative systems (e.g. record-keeping, payroll) and services (e.g. secretarial, accounting) and perform personnel management activities necessary for plant technical activities.

other managers to report directly to the plant manager. However, it is important that the number of people reporting directly to the plant manager be kept reasonably small (preferably not more than 6 or 7). A wide variety of titles and arrangements are used as shown in the actual nuclear plant organization charts of various IAEA Member States in Appendix C.

The plant organization's main lines of communication should coincide with the lines of command to enable plant managers to base their decisions on a full understanding of the plant status. It is, however, impractical for all information to be transmitted from one department to another only through the plant manager. A communication system should be developed to expedite actions which need cooperation among plant departments. It is good practice for the methods of information exchange both within the plant and to external parties to be defined in plant administrative procedures.

If there is more than one nuclear power plant within the utility (and especially if these plants are of the same type), it is feasible to concentrate some functions in utility headquarters in order to avoid duplication of effort in individual plants. The functions which are typically concentrated at or supported from headquarters are engineering analysis, fuel

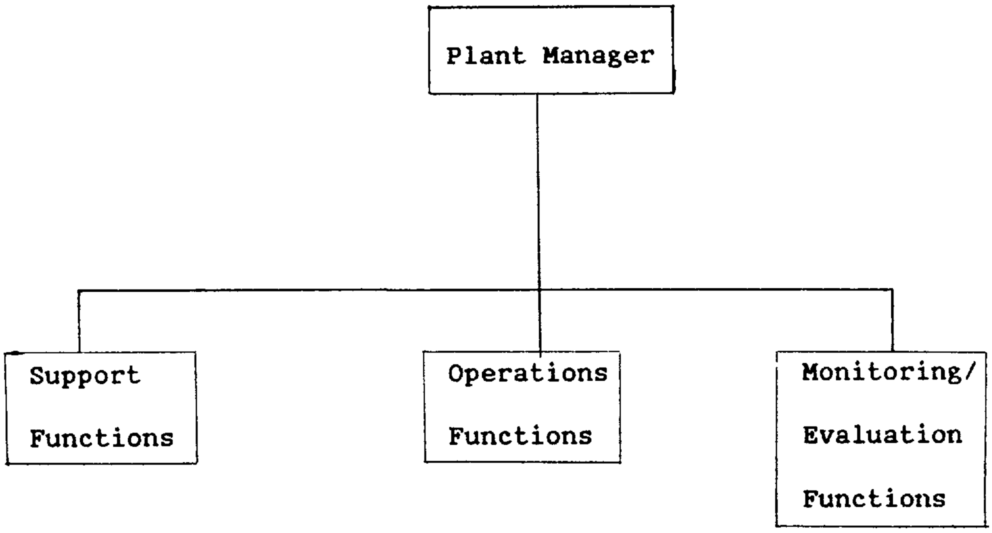

Figure 2.4.-1. Functional organization of a typical nuclear power plant.

management, spare parts procurement and management, fuel procurement, planning and conducting major maintenance work and refueling outages, plant modifications, training, and various administrative functions.

2.5. NUCLEAR POWER PLANT ORGANIZATION DURING OUTAGES

The plant organization during outages remains similar to the organization for day-to-day operation, although an "outage manager" reporting to the plant manager may direct outage-related maintenance and repair work. The control of work performed during outages should be similar to that used for the control of work performed during plant operation. It must be coordinated with control room activities through proper work orders and tagging and must follow health physics procedures (if applicable). Such working discipline is essential to protect both the plant and the workers. However, the work load during outages and refueling is higher than during normal plant operation. To overcome this problem, it is normal practice to hire outside contractors to accomplish specific tasks or (in the case of utilities operating serveral plants) to utilize a headquarters team which moves from site to site undertaking this role. The organization of contractors or the utility outage team should be compatible with the existing plant organization, although the plant organization may need to be modified during the outage. The additional personnel should be fully qualified to perform the work to which they are assigned and should be supervised and/or monitored by the permanent plant staff. They should be aware of relevant site health physics, industrial safety, and security regulations. Training for these workers (general employee training) covering such subjects should be completed prior to commencing their work assignment at the site. There are advantages to using the contractors who performed the installation and testing of plant systems for support during outages (especially in developing countries where it may be difficult to find another qualified contractor).

In planning the number of personnel needed for work during outages, the time limitation for working in a particular radiation field may need to be taken into account. This may result in a considerable increase in the number of qualified workers needed to perform a specific job.

The work procedures and their implementation should be checked and monitored by the plant quality assurance (QA) personnel. The scheduling of outage activities is dependant on the plant operational requirements necessary to maintain subcriticality, residual heat removal and prevention of radioactivity release. For this reason, the outage staff should begin planning and preparation activities well in advance of the outage. The responsible operations staff must be informed of the outage schedule and any constraints as soon as is practical; adequate time must be included for any training they may require and for developing new procedures.

2.6. NUCLEAR POWER PLANT ORGANIZATION DURING EMERGENCIES

The nuclear power plant organization has to accomplish the following functions during emergencies:

- Allow the control room staff to handle the plant controls in the most efficient manner.

- Allow the efficient functioning of the emergency management group.

- Provide technical support to control room personnel and the emergency management group (pertinent information and expert advice).

- Provide maintenance and health physics specialist groups for rapid response to problems with plant components and systems.

- Provide a reliable system of communication between the site, the off-site emergency centre, and applicable government agencies.

The job descriptions of appropriate plant personnel should define their roles in contributing to these emergency functions. Training and regular practice exercises should be provided to ensure that these personnel are prepared to perform these emergency functions if needed.

The on-site emergency management group typically consists of the plant manager, deputy plant manager (operations or production manager), health physics manager, other key members of the plant and headquarters management staff, and a person responsible for outside communications. Their roles and methods of working should be defined in plant administrative and emergency procedures.

The control room staff in emergencies consists of the normal shift crew possibly reinforced (after some time) by several additional operators from other shifts and a few persons giving technical advice to the shift supervisor (shift technical advisor, if relevant) or operations supervisor. The control room composition in emergencies should be defined in plant procedures.

The technical support center staff should include plant specialists for operations, maintenance, and technical services and also outside experts in relevant areas of concern (health physics, etc.).

Both the emergency management center and the technical support center should have direct access to information on plant status, so as to avoid disturbing the control room staff with questions.

The emergency response group is composed of mechanical, electrical, and I&C technicians supported by health physics personnel and equipped with necessary protective clothing, masks, and radiation monitoring instruments and a range of equipment to allow them to enter the affected area to rescue personnel and to make any repair to the plant necessary to control the developing emergency.

The off-site emergency management center communicates with (or is the responsibility of) government authorities; it provides information for release to the public, and recommends public protection measures such as the distribution of potassium iodate tablets, sheltering, or evacuation as necessary.

2.7. NUCLEAR POWER PLANT ORGANIZATION DURING COMMISSIONING

It is essential to have key management personnel and the majority of plant technical staff recruited before the period of plant commissioning. Also, the operators should have completed their training on fundamentals, systems and simulators. The plant commissioning period should be used to the fullest extent for the training of operating and maintenance personnel. Operators should participate in plant commissioning to obtain the training benefits of commissioning activities, such as learning the plant's operating characteristics and gaining operating experience before normal operations begin.

Future maintenance staff should participate in plant construction activities on the systems and components they will be responsible for maintaining. This includes observing the construction and QA activities on systems and components, studying equipment manuals, and developing maintenance procedures based on information supplied by the vendor. This process provides a considerable part of the on-the-job training for the initial plant maintenance staff.

The duties of the utility's operating organization during plant commissioning are typically as follows:

- Establish a system of interfacing with the contractor's construction and commissioning staff to ensure proper performance of planned work.

- Develop or participate in the development of plant startup, operating, maintenance, and surveillance testing procedures.

- Participate in systems testing and verify results against the acceptance criteria.

- Establish and implement procedures for work control (tagging), maintenance, surveillance testing, plant emergencies, QC standards and QA arrangements/procedures.

- Operate the plant systems according to the main contractor's or plant designer's instructions.

- Maintain the plant systems after turnover from the contractors.

One way of accomplishing these tasks is to establish a joint startup team including both utility and contractor personnel (see Fig. 2.7.-1). The joint startup team gradually takes over completed plant systems from the construction organization for testing. If the system meets the acceptance criteria, then it is accepted by the utility's operating organization for operation and maintenance. In parallel with these activities, the operating organization prepares operation and maintenance procedures specific to the plant and based on information supplied by the vendor. This approach allows the plant to be gradually taken over from the constructors and avoids the difficult situation (especially in the case of the first plant in a developing country) when the operating organization has to take over a complete plant in one step. The work of operations personnel during plant commissioning

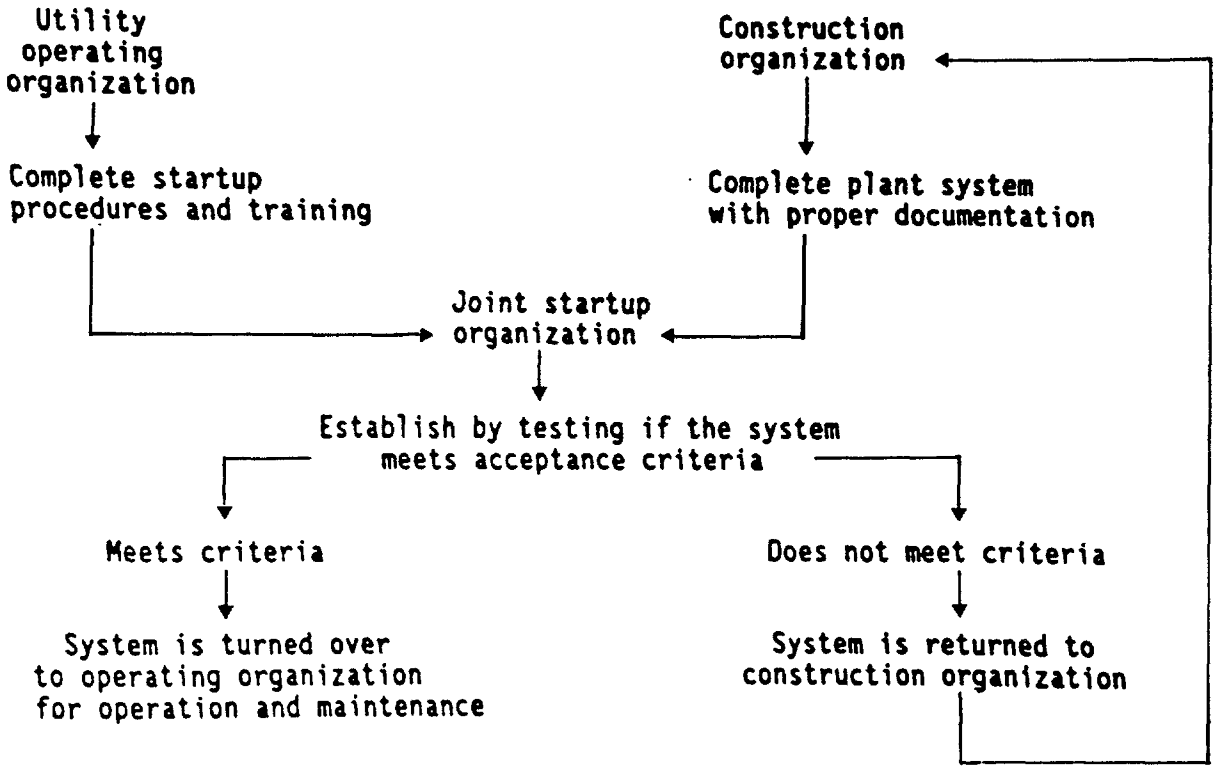

Figure 2.7.-1. Example of a relationship between operating organization, startup group, and construction organization during commissioning.

provides the opportunity for particularly effective on-the-job training which prepares them for formal authorization and hence to operate the plant after the contractors leave the site.

After loading fuel in the reactor, the licence holder has to assume full responsibility for control room operation, because the contractors normally do not have licensed operators in their organization (although they may have individuals with operating experience at similar plants).

2.8. TRAINING ORGANIZATION

Utility and plant managers are responsible for ensuring that plant personnel are fully competent and qualified to perform the tasks assigned to them. Because of the complexity of nuclear power plant systems and operations and the importance of personnel competence for safety, extensive formal training and qualification programs are required. The training organization is responsible for assisting management in establishing, verifying, and maintaining the competence of the plant operations staff. This task can be accomplished by plant or utility personnel alone or with assistance from outside organizations (vendors, consultants, other utilities, educational institutions, etc.). Many utilities choose to establish a separate training centre to conduct training for fundamental knowledge and skills, and to accommodate and conduct training on their simulator(s). The training centre organisation is usually not under the direct control of a plant manager even if it is servicing only one power plant.

The plant training organisation should be independent of the operations function. It should be led by a person of sufficient status within the plant organisation that training activities will be viewed as being of comparable priority to operation and maintenance. This should help ensure that staff will be released from their duties in order to undertake planned training in accordance with the schedule for meeting the needs of all plant staff, which should be approved by the plant manager. The training manager will be supported by a number of training supervisors, instructors and administrative support personnel. The number of staff assigned to him will depend on a number of factors such as the qualifications and number of new personnel to be trained, number of plant staff, extent of training conducted by a utility training centre, the use of headquarters personnel or contractors to provide instructors or entire courses, etc. In a number of utilities, staff members in each function will have time allocated to work with the Training Section on the design and implementation of training making use of their own subject matter expertise. This reduces the number of staff within the training section but can lead to conflicts over the allocation of time between training and work in their own speciality. A survey of utilities in the United States has indicated that developing and conducting training activities account for approximately five percent of the man years at each nuclear power plant.

The establishment of an off-site training centre is particularly beneficial and cost-effective when a utility has more than one nuclear power plant - especially if these plants are of the same type. Even for utilities with only one plant, some training is more effective and efficient if conducted away from the plant. Training activities typically accomplished at a training centre (utility or vendor-operated) include training to provide fundamental knowledge, training on plant systems design, training on maintenance and repair techniques, highly specialized component maintenance training, and simulator training. Plant-specific systems and procedures training and on-the-job training should be conducted at the site. If a utility has plants that are not of the same design, it may still be advantageous to centralize some training while keeping plant-specific training decentralized. The training centre may be located near one of the nuclear power plants. This is especially advantageous if the utility has a series of plants of similar design. In such cases, a large part of plant-specific training can be accomplished in the training centre, and it may be possible to make use of the nearby plant to integrate training centre sessions with plant walk-throughs.

Training in a central training facility has a number of advantages to a utility:

- The best training instructors available from within the utility can benefit more trainees if they are located at a central training facility.
- Better training facilities can be provided more cost efficiently.
- The use of a central training facility fosters the exchange of information between trainees from different plants.
- Trainees may pay better attention to training because they are away from site interferences and distractions.
- The larger number of trainees to be trained permits increased efficiency in conducting training.
- Uniform criteria for verifying competence can more easily be defined and implemented.
- Hardware and software maintenance and updating of centralized simulators can be performed more efficiently.

Training at a central training facility may increase some costs due to trainee travel expenses and has the disadvantage that trainees may not be able to go into the plant to see the things that they have been learning about until some time after their training is completed. These considerations affect the decisions on which training activities should be conducted at a central training facility and which should be conducted on site.

The availability of a plant-specific simulator enables its use in initial and continuing training covering plant systems and normal, abnormal and emergency operating procedures. To support these activities, it is necessary to have three groups of staff:

- Instructors with responsibility for the design, development, implementation and evaluation of all simulator training. They also are responsible for monitoring changes planned at the power plant and deciding (in conjunction with training centre management) which changes need to be incorporated onto the simulator. They will also propose modifications to the simulator based on plant operations and training experience.
- A hardware group with responsibility for maintaining all hardware facilities associated with the simulator. Some of this (e.g. computer routine and breakdown maintenance) may be contracted to the original supplier in those cases where this support can be provided in a timely and cost-effective manner. In considering such an option, the impact of the breakdown of equipment on training for more than a few hours must be considered. Particularly when there is more than one simulator in a training centre, it will usually be preferable and cost-effective to have a high level of competence within the hardware group. This will necessitate the recruitment and training of sufficient staff to care for the full range of equipment and the holding of key spare parts.
- A software group with responsibility for the software associated with the simulator and for its development in accordance with specifications prepared by the instructor group.

The range of software and hardware skills needed to support a simulator installation are considerable, and efficiencies can be achieved when there is more than one simulator to support.

In deciding whether to locate all plant-specific simulators in one training centre or to locate each one near the plant it replicates, a utility will need to consider the following factors:

- The maintenance of uniform standards of training across more than one training centre.
- The benefits to instructors and trainees of the exchange of information fostered by the use of a single training centre.
- The lifetime costs (staff, buildings, simulator procurement and maintenance) of providing separate simulators near each plant (this will be extremely high if there is more than one plant of the same design).
- The cost and time taken for trainees to travel from site to the training centre both for initial and continuing training.
- The availability and cost of accomodations for trainees at or near the training centre.

If there is no plant-specific training simulator available within the utility (or even within the country), then simulator training may have to be performed on a non-plant-specific simulator unless arrangements can be made with an overseas utility or vendor having an appropriate simulator. As discussed in Chapter 4, Section 4.5.9.4., training on a non-plant-specific simulator requires a particular approach in order to provide meaningful training.

The utility organization must ensure good communication and coordination between plant training managers (who report to the plant managers) and the training centre manager in all matters concerning the training process. The training centre manager typically reports to utility headquarters management and is independent of the power plants, but there should be a well-established mechanism for discussion of training issues and needs among the training managers and their management.

The utility should establish a training policy together with any supporting procedures and specifications it considers to be necessary. Periodically it should arrange an independent internal audit of their implementation across its plant(s) and training centre(s), thereby checking that effective mechanisms exists.

2.9. NUMBER OF ON-SITE PERSONNEL

The number of on-site personnel needed to perform the functions defined in Section 2.1.4 should be determined based on the experience of other plants and an analysis of the work to be undertaken by the plant staff. Some major factors affecting the nuclear power plant organizational structure (discussed in Section 2.3.3) also affect the number of nuclear power plant personnel needed. These include the following:

- Plant technology and design

- Extent of utility headquarters support to plant operations

- Utility personnel management and staffing policy

- Availability of external support to the plant for major maintenance, repair or modification work

- Regulatory requirements

A utility starting the development of its own nuclear plant organization should initially consult similar plants and then modify the number of personnel in accordance with its own organization's specific requirements.

The direct operating functions are performed by shift crews. It is normal practice to use eight-hour shifts (although a few utilities use 10- or 12-hour shifts). The number of shift crews used for plant operation depends on utility policy (working hours per week, annual holiday entitlement, etc.) and to a certain extent on regulatory requirements. The number of shift crews may also depend on shift composition (i.e. the availability of replacements within the crew to cover illness and necessary time off). It is generally accepted that 5 or 6 shift crews are needed for smooth plant operation and continuing training, although some utilities use more.

The shift crew composition follows from plant design, utility practice, and regulatory requirements. The typical composition of a shift crew for a single-unit light-water reactor is given in Table 2.9.-1.

TABLE 2.9.-1. TYPICAL COMPOSITION OF A SHIFT CREW FOR A SINGLE-UNIT LIGHT-WATER REACTOR

- Shift supervisor
- Deputy (or assistant) shift supervisor (sometimes called senior control room operator)
- Reactor and turbine operators (control room operators)
- Auxiliary systems operators

The following personnel are available either on-site or on call to the shift team

- Shift technical advisor (or safety engineer); in some plants this function is performed by a senior member of the shift team or by an engineer on call
- Mechanical, electrical, and I&C maintenance personnel
- Health physics and chemistry technicians

With six shift crews and 10 to 12 people per shift crew, 60 to 72 people are typically involved the in direct operation of a single-unit nuclear power plant (not including service and administrative personnel and security guards).

The IAEA conducted a study in 1982 on the number of personnel employed in the nuclear power plants of various utilities and various countries. The results of the study included the following:

- The number of personnel involved with plant maintenance varied between 80 and 120. This number included planning and implementation of mechanical, electrical, and instrumentation and control maintenance activities and site engineering. This number does not cover all the manpower needed for work during refueling outages nor the personnel needed for major repairs or modifications. In such cases, the maintenance department has to be reinforced with outside contractors. The total number of workers may peak during outages at up to 1000 people.
- Health physics, chemistry, and waste management functions jointly were covered by 45 to 60 people (about one third of this number for each function). Health physics personnel may be overloaded during major maintenance or repair activities due to the need to handle radiation protection, to keep records of radiation doses for all workers on site, and to survey, control, and decontaminate equipment, material, and tools leaving the radiation control area.
- The rest of the support and monitoring functions, as identified in Table 2.4.-1, were found to number between 25 and 50.

However, actual practice varied widely from country to country and from utility to utility. In recent years and especially since the TMI accident, there has been a tendency to increase the number of technical personnel in

TABLE 2.9.-2. TYPICAL NUMBER OF TECHNICAL PERSONNEL IN A SINGLE-UNIT NUCLEAR POWER PLANT*

	People	Percentage
Operations function	70	25
Maintenance and site engineering	120	40
Health physics, chemistry, waste management	60	20
All other support functions	50	15
Total on-site technical personnel	300	

* Source: IAEA Survey, 1982

nuclear power plants. The number of shift crews has been increased because of the greater demands of operator continuing training programs; new positions have been introduced such as shift technical advisors (or safety engineers), independent safety evaluation groups, operational experience review personnel; and training departments have increased in size. For example, a 1987 survey of U.S. nuclear power plants showed an average of 500 on-site management, professional, and technical personnel at single-unit plants. This is considerably higher than the figures which were found in other countries through the 1982 IAEA survey and which are given in Table 2.9.-2.

For a utility planning a new nuclear power plant, it is prudent to plan to overstaff the plant with qualified people (especially with licensed operators and others with long training and development programs) by up to 10%, so as to be able to cope with the requirements of documentation, commissioning and early operation and compensate for unplanned losses of personnel. This helps to ensure that there will be sufficient qualified personnel to meet regulatory, safety, and availability requirements.

The number of non-technical nuclear plant personnel (including administration, accounting, procurement, clerical, medical, security guards, fire fighting, transportation, canteen, general services) is typically 25 to 30 percent of the number of technical personnel on-site.

In a developing country, it may be appropriate to employ a larger number of personnel in a nuclear power plant than in an industrialized country, due to the smaller external support available.

2.10. USE OF CONTRACTORS

Some aspects of the use of contractors were discussed in Section 2.1.5. The availability of qualified contractors is very important, especially as a supplement to the plant maintenance and engineering functions. The use of contractors is almost indispensable for major complicated repairs, in-service inspection activities, or the dismantling and servicing of major components (e.g. reactor coolant pumps, turbine generator, steam generators, reactor internals). The contractors selected for the work should be required to have:

- Documented training and qualification to perform the assigned work and, if necessary, the required certification (for example, class 1 welders).
- Experience in performing work of a similar nature
- A well-structured internal organization
- Established and implemented QC and QA programs.(This is of particular importance if the contractor is working on safety-related components.)
- Good supervisory staff for controlling the work
- Available all necessary equipment, tools, and materials
- A reliable system of document control and records management

The contractor-utility interface on-site may vary. In most cases, contractor personnel are included in working groups within the existing plant maintenance organization. It is also possible for contractor personnel to accomplish a job independently of plant personnel. This may be the case when a specific work package is well-defined and work quality can be effectively verified by utility personnel before the work is accepted.

Radiation exposure may limit the time allowed for a worker to perform an activity. This can make it necessary to increase the number of personnel needed to complete the activity and, thus, may require the use of contractors. In cases when highly qualified and skilled workers are needed, this may be a limiting factor for the timely completion of the repair or maintenance. When simple and well-defined actions are to be performed in radiation areas, it is feasible to use unskilled or semi-skilled workers recruited from among people who are not normally nuclear plant workers. These workers are trained in radiation protection principles and practices and also receive training on mock-ups in order to shorten their time in the radiation area to a reasonable minimum.

The health physics coverage of contractor workers is normally the responsibility of the plant health physics personnel. Prior to undertaking any on-site activity, contractor workers must be trained on the plant health physics and other applicable plant procedures.

In the case of a developing country, it may be difficult to obtain qualified contractors in the country. One possibility is to use local contractors who worked on the plant construction (usually as subcontractors to the reactor vendor). However, some activities will necessitate the employment of foreign contractors.

2.11. MANAGEMENT DECISIONS AFFECTING TRAINING

Management decisions and actions related to orgainzation and staffing are of prime importance to the success of nuclear power plant training. Management should be personally involved in ensuring that plant personnel are properly trained and qualified for their work assignments. In addition, management is responsible for the establishment of strategies and policies with significant impact on the training organization and its activities, such as the following:

- Establishing the plant organizational structure
- Defining the policy for staffing (i.e. determining the staff size, identifying which positions require increased staffing, and determining the extent/amount of use of outside support)
- Establishing the interrelation of a nuclear power plant with other nuclear and fossil power plants in the utility system, with respect to staff recruitment and staff movement
- Defining the criteria and timing for staff recruitment and training at the plant and the functions to be performed by utility personnel during plant commissioning
- Defining the training organization (centralized or decentralized)
- Recruiting qualified training instructors and supervisors or developing employees to undertake this role
- Deciding upon the feasibility and scope of the training centre and training facilities, including training simulator(s)
- Ensuring that work load and shift rotation allow sufficient time for the plant staff to participate in continuing training to maintain their competence
- Securing contracts for training services with the reactor vendor, another utility, or a suitable consultant in cases when locally available training capabilities are not sufficient

2.12. SUMMARY

- The structure and functions of a nuclear power plant organization should be reflected in a set of positions that collectively comprise all the duties, responsibility, and authority necessary for safe, reliable and efficient plant operations.
- The nuclear power plant organization should be structured to include clear lines of command and communication. The functions of all plant positions should be well-defined and should include direct operating functions, supporting functions, and monitoring/evaluation functions.
- The plant organizational structure, staffing levels, and training programmes should ensure that an adequate number of qualified personnel are and will at all times be in place to perform required normal, abnormal, and emergency functions.
- In planning the staff necessary for plant operations, it is advisable to allow for some overstaffing (especially for key functions which have long training programmes).
- An effective training organization is essential for developing and maintaining a fully qualified plant staff.
- The use of training centers offers significant advantages over training conducted exclusively at the plant site.

- The use of contractors to assist the plant staff is essential for major repairs, for dismantling large components for maintenance, and for some specialized services. The availability of qualified contractor personnel is important in accomplishing these functions.

- The availability of outside assistance for refueling outages and for major repairs has a significant influence on the size, structure and competence requirements of the plant organization.

- Utility management is responsible for ensuring that plant personnel are fully qualified and for the efficient functioning of the plant organization. Management has to establish manpower development strategy and staff recruitment policy and must define/decide on the training organization and training facilities.

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Chapter 3

PERSONNEL EDUCATION, RECRUITMENT, AND SELECTION

3.1. INTRODUCTION

Nuclear power plants are high-cost investments, and the only way to obtain competitive energy costs is for nuclear power plants to achieve high plant availability. Also, nuclear power plants present a potential threat to health and the environment, if they are not operated safely. One key factor in achieving plant safety and availability is the competence of the staff. The availability of a highly qualified and competent staff is a common interest of utilities, regulatory authorities, and the general public.

As described in Chapter 4, the educational background of personnel hired for employment in a nuclear power plant is one of the main considerations in designing the training and qualification programmes intended to develop the skills and knowledge required for specific positions. In some cases, training is designed and provided to substitute for and supplement education.

The recruitment and selection of personnel with the ability to meet established competence requirements is essential for safe, reliable plant operation. Without proper personnel selection, even the most intensive training cannot achieve the competence required for plant positions. Personnel selection criteria include not only educational background, knowledge, skills, experience, and aptitude, but also appropriate personal characteristics (such as attitudes, physical and mental health, etc).

This section discusses educational systems applicable to craftsmen, technicians, and engineers in various countries with emphasis on the influence of educational systems on the nuclear power plant training process. In addition, some basic considerations and practices in nuclear power plant recruitment and selection are presented.

3.2. EDUCATION SYSTEMS

Because the purpose of this Guidebook is to discuss training to establish and maintain competence of nuclear power plant operations personnel, only those portions of an education system dealing with the education of technical personnel are considered.

The education system in any country provides fundamental knowledge and skills and thus establishes the base for any nuclear power training programme. Technical education systems are similar in many countries, and it is possible to discuss some of their common characteristics.

Nuclear power plant technical positions can generally be divided into three levels: craftsmen, technicians, and university-level (graduate or professional) engineers/scientists. These three types of positions are generally associated with three different levels of education, although the relationship varies somewhat from country to country.

A typical technical education system is shown in Figure 3.2.-1. The first six to 12 years of education is of a general nature and is basically the same for the total population, although some specialization may occur during the last three to four years. The education system is usually divided into

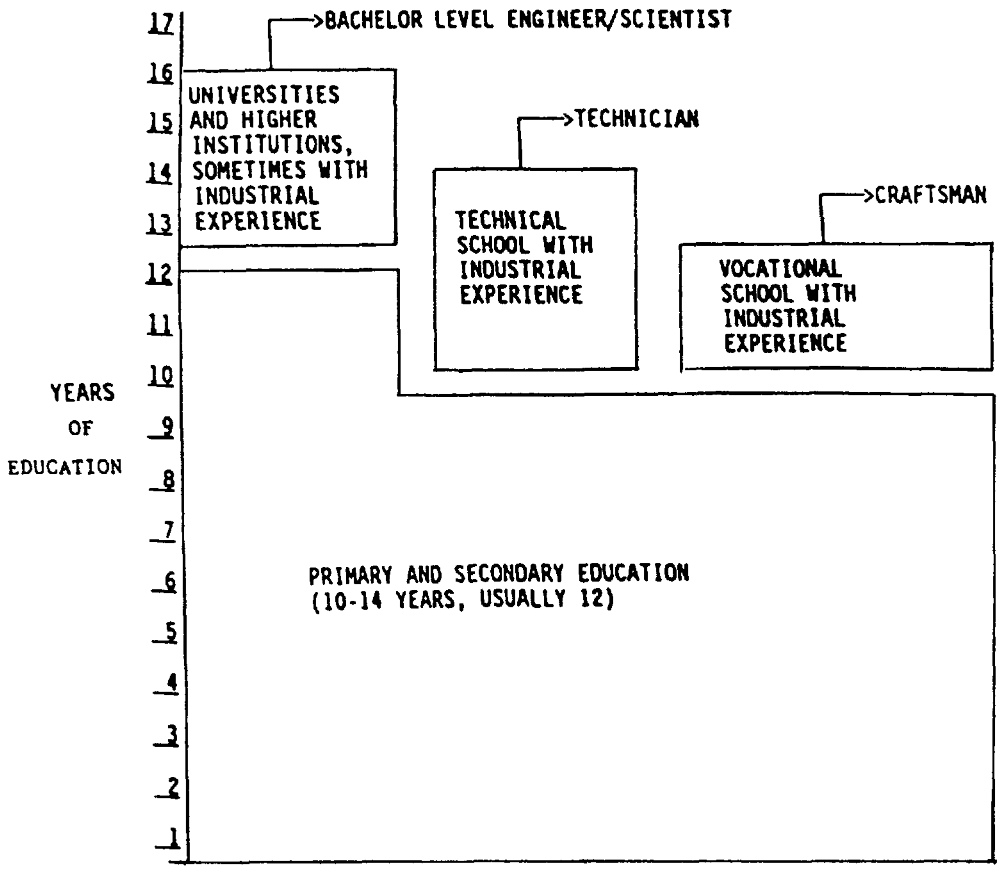

Figure 3.2.-1. Typical technical education system.

primary and secondary schools. In most countries, primary school education (usually corresponding to the first six to eight years of education) is obligatory and teaches basic knowledge to all three groups. Secondary school (aimed at completing basic education during an additional three to six years) is a prerequisite for studies at a university. See Appendix D for actual educational systems in several IAEA Member States.

University education in most countries lasts four to five years. The total period of education required for the first university degree (bachelor) is therefore approximately 16 to 17 years. Additional university education resulting in higher university degrees (masters degree or doctorate) lasts two to four years longer.

Technical schools produce technicians of various specialties (mechanical, electrical, electronic, chemical). The courses in technical schools put emphasis on applied rather than basic science. They include a large amount of practical work which is often accomplished in industry. The duration of education in technical schools is three to six years. In the Federal Republic of Germany, the requirement for admission to a technical school is the successful completion of three to three and a half years of vocational training and two years of industrial experience in the corresponding field. In some other countries (e.g. United Kingdom), the education of a technician can be completed by alternating periods of training in technical school and practical experience in industry.

Technical education in a vocational school prepares a person to be a skilled worker or craftsman. The emphasis is on developing craft skills, which requires a high proportion of practical work. Practice is often obtained by working in industry (in an apprentice programme) as part of the vocational education. Academic teaching in vocational schools is limited to the topics needed to support practical tasks. Total time spent in education to prepare to be a craftsman is about 12 years.

Education systems usually allow vocational school graduates to continue their education to the level of technician and the better technical school graduates to continue their education at a university.

Although technical education systems are similar in many countries, large differences in the knowledge and skills of graduating students have been observed. In developing countries, the technical abilities developed by the education system are sometimes limited (see Chapter 6, Section 6.3.2.).

To overcome some of the deficiencies in the education system, it is possible in some cases for the education of a limited number of personnel from developing countries to be undertaken in an industrialized country.

Although some of the problems described above exist also in industrialized countries, the technical education programmes in those countries generally put more emphasis on practical industrial training (apprenticeship training in industry and vocational school), and this gives the students an insight into the application of modern technologies and techniques. This is particularly true in the training of technicians, whose education programmes differ significantly between countries. The education programmes for technicians in industrialized countries include a substantial variety of the specialties (knowledge and skills) needed in modern industries.

3.2.1. Engineers/Scientists

In countries adopting a nuclear power programme, the education programme is often expanded to cover nuclear science and nuclear power technology. This additional education is usually confined to universities and, in many cases, is part of specialized postgraduate studies. Courses and training in nuclear subjects cover basic and advanced theoretical and practical aspects of nuclear physics and engineering. Nuclear technology requires nuclear engineers, but also requires capable engineers from conventional engineering disciplines (mechanical, electrical, electronic, chemical, and civil) and graduates in the physical sciences, with some supplementary education in areas unique to nuclear power technology.

3.2.2. Technicians

As a general rule, the education of technicians should provide them with the following:

- A good grasp of the basic sciences which are the foundation of the area of technology in which they will be working.

- In-depth knowledge of fundamentals in their area of technology.

- Practical training and experience in the application of their knowledge and skills.

- An overview that describes the interfaces between their specific field of technology and the technologies with which it interacts.

- The capability to communicate, which includes oral, written and technical communication (e.g. mechanical drawing, electrical and electronic circuit diagrams).

Technicians need not be too highly trained in manual skills, but they should be familiar with the work of craftsmen and the skills they employ.

3.2.3. Craftsmen

The education of craftsmen takes place, in most cases, in vocational schools which should be especially equipped to give hands-on education, or through apprenticeship programmes. After such education, they should have access to on-the-job training. The craftsmen in operating plants are usually included in maintenance teams.

3.3. EDUCATION REQUIREMENTS FOR NUCLEAR POWER PLANT PERSONNEL

The most frequently required technical disciplines in a nuclear power plant are mechanical, electrical, and I&C engineering. These disciplines are needed for many direct operating, support, and monitoring functions. Chemistry or chemical engineering is needed for chemical and waste treatment functions, physics or nuclear engineering for reactor physics and fuel management functions, and physics or health physics for radiation protection functions. The personnel involved in direct operating functions must be sufficiently knowledgeable about the basics of all the disciplines affecting plant operation.

As far as educational requirements are concerned, the following are common practices followed in most countries and also expressed in IAEA guides:

- Managerial positions (plant manager, deputy plant manager, operations manager, safety manager, maintenance manager, QA manager, and training manager) should be occupied by university level engineering or physical science graduates. Additionally, in some countries, it is a requirement that the first four of these positions also have masters degrees in engineering.

- The other positions for which a university-level education is normally required are: shift technical advisor and safety engineer. Reactor physicists, health physicists, plant chemists, and maintenance engineers will generally have university degrees, and some of the more junior staff may also have received a university-level education.

- Of the shift crew, the shift supervisor is preferably a university-level graduate engineer. Although increasingly found, this is not the general rule (especially if a graduate engineer is included in the shift or is available on call). Others within the shift crew may also be university-level graduates, but this is not usually the case.

- The remaining technical positions are filled by vocational and technical school graduates.

Appendix D lists the education and experience requirements for key nuclear power plant positions in some IAEA Member States.

How and to what extent university graduates are used on the plant staff depends (among other things) on the availability of utility headquarters assistance to plant operations.

In the experience of some utilities, employment of university level engineers on shift work in the control room can present particular challenges to the power plant management. Such work can be quite monotonous, and university graduates may not find satisfaction in undertaking shift duties for a long time unless additional tasks which utilize more of their abilities can be assigned to them. The utilisation of graduate engineers and of technicians within shift crews and in more senior positions has to recognise both the career ambitions of staff and the need to maintain stability within shift crews as the means of accumulating operating experience and of developing teamwork.

Owing to the considerable differences of abilities developed by the educational systems in various countries, meeting the required formal educational qualifications is generally not in itself sufficient. Each country, on the basis of an analysis of the actual abilities (knowledge and skills) developed by its own educational system, should decide upon the desired educational qualifications needed for each particular position in its own plants.

The educational qualifications for some nuclear power plant positions are prescribed by the regulatory authorities. This practice has been introduced in a number of countries since the TMI accident.

Some developing countries have tried to compensate for weaknesses in their educational systems by requiring higher educational degrees for some plant positions (even doctoral degrees). This may partially solve the problem, but the weaknesses of educational systems is in most cases caused by poor practical training and not by insufficient theoretical knowledge. (see Chapter 6).

3.4. RECRUITING GOOD CANDIDATES

Nuclear power plant economics and safety considerations provide a great incentive for a utility to attract high quality manpower. Individuals recruited for nuclear power plant work should already have some knowledge and skills in areas required for their specific positions. In addition, the process of selecting which candidates to hire (or promote) should be able to determine their aptitude for learning and their likely capability to perform the job.

Good candidates may be attracted to apply for employment in nuclear power plants due to the following:

- A good record of personnel safety in nuclear power plants

- A clean environment (especially compared with other heavy industrial work)

- The possibility of improving intellectual knowledge and manual skills through specialized training

- Work in an advanced technology

On the other hand, there are aspects which make the recruitment process more difficult and the work more demanding:

- Very demanding and lengthy training programmes which are required to become qualified for the higher level positions in a nuclear power plant
- The requirement (for some positions) to obtain and maintain licenses from the regulatory authority
- Highly specialized training (particularly for operators) with limited applicability to other industries (this restricts the opportunity to change job and work location and is particularly significant when there is only one nuclear plant in the country.)
- The requirement to maintain competence by continuing training and requalification
- The responsibility borne by nuclear power plant operations personnel, which is higher than in most other industries, because of the large costs and impacts of outages and errors
- The requirement that more senior personnel be promptly available on call outside normal working hours
- In remote sites, the difficulty in finding suitable schools and the limited employment opportunities for other members of the family
- Actual and perceived public opposition to nuclear power

Utility management must be aware of these problems and must offer good candidates especially attractive employment terms (e.g. career prospects, good salaries and benefits, attractive housing, recreational opportunities, extended vacations, etc.).

3.5. SELECTING QUALIFIED CANDIDATES

The selection of individual candidates for specific positions in a nuclear power plant is a very important step (perhaps the most important) in ensuring that there are a sufficient number of qualified operations personnel. To accomplish this task, different countries have adopted different approaches, and none of these approaches is the best for all utilities. Some find it beneficial to confirm the selection by the use of a probationary period after satisfactory completion of the initial training programme.

There are a great number of factors to be considered in judging a person's characteristics, including attitudes, intelligence, skills, social behavior, stress resistance, etc., every one of which is important in plant operations. Selection criteria are usually divided into two categories:

- Formal requirements such as age, medical fitness, education, previous experience, and knowledge of a relevant foreign language (if necessary for training overseas)
- Evaluation of the suitability of the candidate by applying the following methods:
  . Analysis of the candidate's personal history
  . Interviews
  . Tests (knowledge, skills, aptitude, physiological and psychological)

3.5.1. Education Qualifications

The education requirements for nuclear power plant operations personnel were discussed in Section 3.2.

3.5.2. Practical Experience

A condition for assignment to many positions in a nuclear power plant organization is that the candidates should have practical work experience in fossil and/or nuclear power plants. The prescribed number of years of such experience varies from country to country and from utility to utility. The experience includes both fossil and nuclear plant experience, but the nuclear plant experience should not be less than about 50% of the total in the case of the more senior personnel.

See Appendix E for examples of the education and experience requirements of nuclear power plant personnel in various IAEA Member States.

For the first nuclear plant in a country, it is not possible to satisfy these requirements for nuclear experience. In such cases, the requirements may be limited to fossil power plant experience supplemented by experience acquired during training or during nuclear plant start-up and commissioning. For further discussion of the problems associated with recruitment for the first nuclear power plant in a country, see Chapter 6.

3.5.3. Personal History

Personal history includes a set of data provided by the candidates in a specified format (i.e. answers to a questionnaire) on their educational history, previous employment and qualifications, special interests, etc. If such information is reviewed by an experienced manager, a judgement on the candidate's personal characteristics can be made, for example, on the ability and willingness to learn, potential for career development, motivation for improvement, capability for team work and leadership, etc.

3.5.4. Interviews

The interview, in its various forms, is one of the most widely used methods of obtaining information on candidates. A skilled interviewer can develop the information supplied on the personal history questionnaire and obtain further information about most aspects of the candidate. Questioning can reveal not only a person's knowledge, abilities, and attitudes and confirm the judgement of his potential, but also indicate his behavior in favourable conditions and under stress and indicate his adaptability to the nuclear power plant operations team environment.

In most cases, interviews are conducted by the senior staff of the department to which the candidate has applied and who themselves have had training in interviewing techniques.

3.5.5. Tests

Specially prepared tests have been found useful and efficient in aiding the employee selection process. A set of tests, properly designed, can provide objective information on the candidate.

Medical tests should determine the physical state of an individual against the job requirements. They should also be designed to detect abuse of drugs and alcohol. Such tests should be undertaken prior to initial appointment and at regular intervals throughout the period of employment.

Some utilities are beginning to make use of psychological testing to support initial selection.

General tests are available to evaluate intelligence, personality factors, aptitudes, various manual skills, and mental abilities. Special tests have been designed to test specific knowledge and skills related to nuclear power plant jobs.

Selection tests must be reliable and valid (i.e. not influenced by external and chance circumstances and accurate in measuring the intended personal ability). An advantage of tests is that they usually give numerical scores which allow the use of quantitative acceptance criteria, and this in many ways is more objective than an interview in judging these factors.

Written selection tests are most widely used in the United States. As an example of such use, special tests (known as the Plant Operator Selection System and the Maintenance Selection System) have been applied by some U.S. utilities in the selection process for operators and maintenance personnel. The operator test is comprised of aptitude, experience, and personnel indexes.

The aptitude index includes the following:

- Reading comprehension (ability to interpret written instructions)

- Spatial relations (ability to visualize the properly assembled form of an object)

- Mechanical concepts (ability to understand mechanical principles)

- Mathematical usage (skill in solving and manipulating mathematical relationships)

- Perceptual speed and accuracy (speed and accuracy in interpreting data)

Experience and personal indices relate to the candidate's previous experience and personal characteristics. Many utilities use additional tests to measure the personality profile or emotional stability of a candidate (such as the Minnesota Multiphasic Personality Inventory - MMPI). In some countries it is a requirement of the regulatory body that such tests be given for certain direct operating positions.

3.6. THE SELECTION DECISION

The combined results from a candidate's personal history, interviews, tests, and additional data are used as a basis for the decision on selection. Sometimes there are inconsistencies in the data; for example, test results may not agree with the expectations based on the interview and the personnel history. In these cases, some follow-up investigations may be necessary before deciding which candidate to hire or promote.

The selection decision has to be based on predetermined criteria, to reduce the influence of subjective factors. It is advisable that the decision be made by a group of skilled and knowledgeable utility staff who are familiar with the competence required for the position to be filled and with the personnel policies of the utility.

The utilities in some countries (e.g., France, Federal Republic of Germany, United Kingdom) use additional methods for selection of candidates for control room positions. These involve selecting students to be sponsored during their education in universities or technical schools and observing their progress and attitudes during an extended period, or observing the personal qualities of a group of utility employees over a period of one to four years prior to selecting from this group candidates for reactor operator and senior reactor operator training.

3.7. CAREER DEVELOPMENT

Competent staff are of considerable value to the utility, and utility management should seek all possible means to encourage the career development of individuals up to their maximum potential.

The utility should provide the means and incentives to stimulate employees to learn and improve their intellectual abilities and manual skills. Individuals will respond to a requirement for continuing education and training more willingly if there are prospects for promotion to better positions and for more attractive wages and working conditions.

As part of career development policy, a utility should include regular monitoring of employee job performance, attitudes, skills, and behavior. This is necessary to select the best candidates for promotion. Promotion may be effected directly by management decision (for example, the promotion of a craftsman to a foreman position) or through a successive training and examination process. Such a process is frequently applied, for example, to qualify craftsmen, technicians, and engineers for control room duties as licensed reactor operators or senior reactor operators. The career development for such personnel is realized through classroom training, examinations, and on-the-job training during a period of several years.

An effective method to broaden an individual's experience is by applying a job rotation scheme with an appropriate working period at each position. This gives the opportunity for individuals to get acquainted with specific tasks of the various plant positions, which is particularly important for future managers. However, it must be recognized that the individual must be properly trained and qualified for each position to which he is assigned; otherwise the individual must work under close supervision.

The promotion of plant personnel to some positions may be limited by their education. If a position requires a university degree, then an individual without a degree cannot be promoted to that position. In some special cases, the utility can make an exception and accept less educated individuals than ideally required for a position (if this is not prohibited by regulatory requirements). This may be the case for a person having extensive experience with the utility. Some utilities provide additional education for selected employees by sponsoring full-time education or by arranging suitable working hours to allow the pursuit of additional education.

3.8. SUMMARY

- The technical education system in most countries consists of general education (divided into primary and secondary schools) and technically oriented education (vocational and apprentice education, technical schools, technical universities).

- The total education period for craftsmen is about 12 years, for technicians 12 to 14 years, and for (technical) university graduates 16 to 17 years.

- The difference in abilities developed by the education systems of different countries are significant. Many developing countries experience difficulties in organizing technical education systems oriented towards the needs of modern technologies. This is due to inadequate teaching facilities, insufficient qualifications and/or experience of the teaching staff, and lack of an industrial tradition.

- The managerial positions in a nuclear power plant are mostly occupied by personnel with university degrees in engineering. Leading personnel in the maintenance, technical services, health physics, and chemistry departments and shift technical advisors also normally have university degrees in engineering, physics or chemistry.

- Shift supervisors are preferably university graduates, but, in many cases, these positions are occupied by individuals without engineering degrees.

- The remaining plant positions are filled by vocational and technical school graduates.

- Attracting and retaining competent personnel to plant operations is of great importance because this is one of the key factors in achieving high plant availability and safety.

- Compared with other industries, employment in a nuclear power plant has special advantages and disadvantages that affect the recruitment process and the retention of personnel.

- Selection of nuclear power plant operations personnel includes prescribing formal acceptance criteria (such as age, education, experience, health etc.) and evaluating candidates' personalities, skills, knowledge and aptitudes through review of personal history, interviews, and tests.

- Utility management should, as part of the personnel development policy, stimulate personnel to improve their knowledge and skills. This can be achieved by combining on-the-job training and job rotation with classroom training. It is also important to provide career development opportunities.

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Chapter 4

A SYSTEMATIC APPROACH TO INITIAL TRAINING

4.1. OVERVIEW OF A SYSTEMATIC APPROACH TO TRAINING

4.1.1. Introduction

It is generally accepted that developing training programmes based solely on experience is inappropriate for the nuclear power industry.

A systematic approach to the development and implementation of initial and continuing training programmes together with the development of training solutions to operational problems is the most cost-effective and comprehensive approach. With this method, it is assured that all job competence requirements are established and achieved, thus ensuring that the human aspects associated with high nuclear safety and availability are not compromised. Operational experience is used to review and upgrade training programmes developed using a systematic approach.

Without an adequately systematic approach, there is a risk that important elements will be omitted, thereby adversely affecting safety and availability. There is the further potential that programmes will be too extensive for the needs of the job, with the consequent cost implications.

A systematic training and qualification process has the following advantages over traditional approaches to training:

- It identifies the specific competence (knowledge and skills) needed for each job (or position).

- Training programmes are developed with explicit learning objectives and with content that meets the trainees' needs.

- Training is conducted as it was designed to be conducted and is conducted in the same manner for all trainees.

- Trainees master the learning objectives (have the required competence) before they begin work in their assigned positions.

- Training programme results are carefully evaluated, and the training programme's effectiveness is maintained and improved.

- The use of a systematic approach to training and qualification permits greater management control and increased accountability.

In this chapter, the principal activities of such an approach as it applies to initial training are presented. Chapter 5 describes the application of a systematic approach to continuing training.

The implementation of a systematic approach to training varies from utility to utility and from country to country for several reasons. For example, the application of a systematic approach to the development of a new programme where no training has been conducted might involve all of the activities described in this chapter, while only selected activities might be necessary to improve an existing program that has been conducted a number of times. With experience, some utilities may find certain activities to be essential, while other activities may have to be modified or their purposes accomplished in a different manner. Also, depending on the circumstances, the sequence of performing the activities may vary. For example, the evaluation of an existing programme would lead into activities of one or more of the other phases to make required improvements. These factors should be kept in mind when applying the guidance contained in this Guidebook.

The importance of a systematic approach to training, including job and tasks analysis, has been recognized by many utilities (particularly in the United States of America). A survey of OECD member countries, performed by the Committee on Safety for Nuclear Installations (CSNI), revealed that the majority of these countries have also applied this method in the development of their nuclear power plant training programmes. However, in most of these countries, this approach is not applied in the same depth as in the U.S.A; in some countries it is used only for control room staff.

The steps to establish performance-based training include a number of activities. The activities are as follows (See Figure 4.1.-1.).

Analysis

- Conduct needs analysis
- Conduct job analysis
- Select tasks for training
- Conduct task analysis

Training programme design

- Establish performance standards
- Select training setting (environment)
- Determine trainee entry-level knowledge and skills
- Develop learning objectives
- Organize and sequence learning objectives
- Develop test items
- Construct tests
- Develop training plan

Training programme development

- Specify learning activities
- Select training methods
- Develop training materials
- Develop lesson plans

Training programme implementation

- Implement training plan
- Select and train instructors
- Conduct training
- Assess trainee performance
- Document training

Training programme evaluation and improvement

- Collect information
- Analyze information
- Initiate corrective actions

This section briefly discusses the main steps necessary to establish a systematic approach to training. Sections 4.2. to 4.6. discuss major aspects

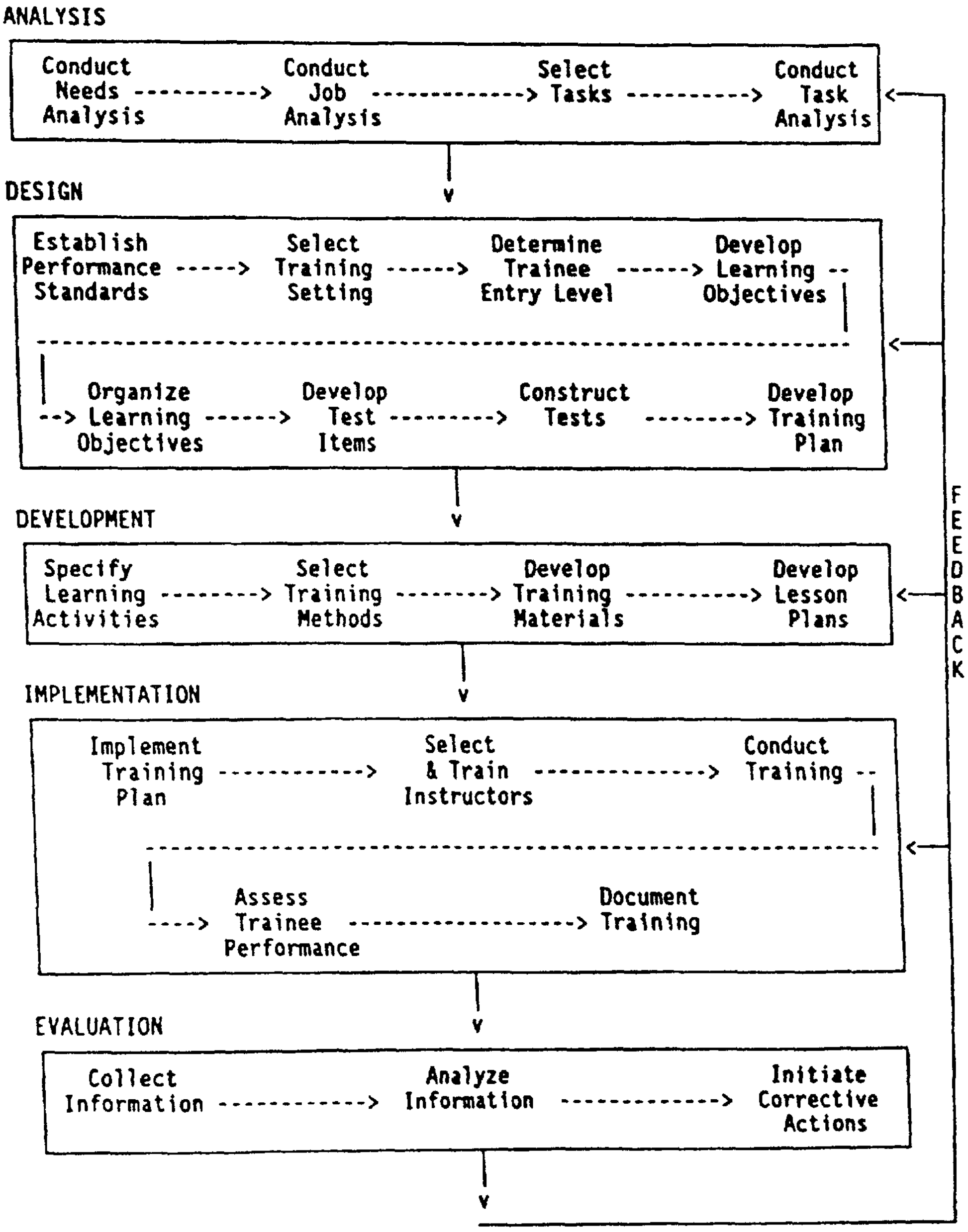

Figure 4.1.-1. a systematic approach to training.

of selected activities in more detail and are cross-referenced in the brief description of the approach which is given in this section.

4.1.2. <u>Analysis</u> (see Section 4.2)

Experience has shown that traditional topic-based training does not ensure that all knowledge and skills required for a specific job are included in the training or are mastered by trainees before assignment to that position. The analysis process identifies the required knowledge and skills, so that they can be included in the training programme.

4.1.2.1. Training Needs Analysis

The first step in analysis is to define training needs. This is a prerequisite for decisions on the necessity for developing or making improvements in a training programme. If no training exists, the development of a training programme is obviously needed. Where a training programme exists, the needs analysis process starts with collecting information on the performance of job incumbents, job performance deficiencies, changes in known information needs (due to lessons learned from plant experience), and changes in plant systems, documents (procedures, technical specifications, etc), and regulatory requirements. Performance problems and the above-mentioned types of change imply a possible need for improvements or changes to training.

The needs analysis process examines performance needs and deficiencies and identifies the appropriate solutions. Changes or additions to training programs may or may not be needed to accomplish the improvement. Other possible solutions to performance problems include improved procedures, equipment modifications, and/or improved supervision. Only if training needs are identified does the process continue to the job and task analysis steps.

4.1.2.2. Job Analysis and Task Selection (see Section 4.2.3)

Job analysis is a process to produce a list of tasks to be included in the training programme for a specific job. This list clearly and accurately defines the activities performed on the job. The description of a task should include the corresponding performance standard; this permits subsequent development of learning objectives and trainee performance standards. Input for job analysis includes plant documents (e.g. job procedures and manuals), surveys, interviews, and the results of similar analysis from plants of the same type. (It is important to review and modify the data obtained from other plants to assure its applicability). Job analysis also includes identification of required work attitudes such as safety awareness (operational and industrial safety) and fitness for duty.

If the data needed to specify the tasks are not available in plant documents, the job analysis has to include surveys and/or interviews with job incumbents and supervisors. In either case, supervisors should review the list of tasks. The review should confirm that the task lists are complete for each job and that they include all tasks necessary for safe and reliable plant operations.

After the tasks have been identified, those that need to be included in the training programme are selected. Tasks which should be selected are those which are difficult to learn and are important for plant performance and safety (i.e., whose improper performance represent the greatest risk). In making this selection, one should also take into account how frequently a task is performed. Task selection is very important and should be done by experts and training personnel aided by quantitative information obtained during job analysis. (It should be noted that the criteria for selecting tasks to be included in initial training are different from the criteria for continuing training.)

4.1.2.3. Task Analysis (see Section 4.2.4)

Tasks selected for training should be analyzed to determine the required knowledge and skills. Results of task analysis provide data from which performance standards and learning objectives are developed or verified.

The data necessary to perform task analysis is extracted from plant documents or from other sources (interviews with job incumbents and others, existing training materials, feedback, experience, data on plant modifications, etc.). Task analysis should be conducted by experienced and knowledgeable persons using standardized methods.

Many skills and knowledge areas are common to several tasks. To avoid redundancy in training programmes and to allow more efficiency in their development, such skills and knowledge should be grouped and uniformly classified (for example, theoretical knowledge or basic principles, components design characteristics and functions, systems design and interrelations, etc.).

4.1.3. Training Programme Design (see Section 4.3)

Design of a training programme uses the list of tasks selected for training and the required knowledge and skills identified during task analysis. Design activities use this information to produce specifications for developing and implementing the training programme.

4.1.3.1. Performance Standards (see Section 4.3.2)

Since the aim of performance-based training is to establish the job performance capabilities of personnel, it is necessary to establish the standards for personnel performance. The performance standards are used as terminal objectives of training for the particular job, i.e., as the training goals, in terms of measurable employee performance, that are used to assess trainees upon completion of training. These performance standards are derived during the analysis phase.

4.1.3.2. Training Setting or Environment (see Section 4.3.3)

An early activity in training programme design is the selection of the training setting (environment). Possible settings include the following:

- Classroom
- Laboratory or workshop
- On-the-job training
- Simulator
- Self-study

The selection depends on the nature and importance of the knowledge or skill to be learned. For example, knowledge and skills for learning the most important control room tasks requires high-fidelity training, involving the use of full scope replica simulators. On the other hand, for the fundamental knowledge required for many tasks, classroom training is appropriate. On-the-job training is necessary to provide experience in the actual work environment and is an essential part of the training programmes for all personnel. In addition to developing required skills, on-the-job training develops self-confidence. Workshop or laboratory training is important for development of basic and advanced skills that support task performance, especially for maintenance personnel.

4.1.3.3. Trainee Entry Level (see Section 4.3.4)

As a part of the design of a training programme, it is important to determine the entry level knowledge and skills of potential trainees. This is necessary to establish the prerequisites for entering the training programme and to develop the learning objectives. Learning objectives are developed to fill the gap between entry-level knowledge and skills and those required for job performance.

4.1.3.4. Learning Objectives (see Section 4.3.5)

Learning objectives describe what is to be learned in terms of measurable trainee performance. Learning objectives are the essential input for development of a training programme - they define the programme content. Terminal learning objectives define trainee competence expected upon completion of training. Other objectives, referred to as enabling objectives, describe trainee capabilities needed before terminal objectives can be accomplished.

The terminal learning objectives are based on the required task performance and include the associated job performance standards. Enabling objectives are developed based on the assumed entry skills and knowledge possessed by the trainees; they fill the gap between entry skills/knowledge and the terminal objectives.

Learning objectives includes the conditions under which the required action will be performed as well as the standard for acceptable performance.

After all learning objectives for a particular training programme are developed, they must be organized and put into a logical sequence for instruction. The objectives are grouped by training setting and are sequenced for effective learning, generally starting with simpler prerequisite knowledge/skills and proceeding to more complex topics. It is beneficial for the trainees to be issued with the learning objectives for reference during the training programme.

4.1.3.5. Test Items and Tests (see Section 4.3.6)

Test items and tests should be developed during the design phase of a training programme. Written, oral, and performance tests are used for trainee assessment during a training programme and after training is completed. Written and oral tests are generally used to assess knowledge, while performance tests are intended to assess trainee competence or skill in performing tasks under actual or simulated work conditions. The main inputs to test item development are the performance standards and the learning objectives. The learning objectives specify the skills and knowledge that must be assessed in tests. If possible, several test items should be prepared for each learning objective.

Tests may be used in three different ways: (1) pre-tests can be administered to confirm trainee preparedness to enter a training programme or identify needed remedial training, (2) progress tests are used to ensure that trainees are mastering the learning objectives, and (3) post-tests assess whether trainees are prepared to go on to subsequent training or if they have the competence required to be assigned to a particular task or job.

Each type of test is constructed using test items that are based on the applicable learning objectives. For example, a progress test to be given at the end of one module of a training programme should include questions covering a representative sample of all learning objectives in that module. The number of questions or the assignment of their point values should be based on the relative importance of the associated learning objectives.

4.1.3.6. Training Plan (see Section 4.3.7)

A training plan is developed to describe how the training programme will be conducted. It includes the sequence and schedule of instruction, the training setting for each segment of training, the times at which tests are to be given, and the needed facilities and equipment.

4.1.4. <u>Training Programme Development</u> (see Section 4.4)

During the design phase, the inputs for training programme development are produced: the learning objectives (measurable goals of the training programme) which are organized and sequenced for efficient training, and the training plan which guides the development process. The development of a training programme consists of a set of activities needed to convert the established training requirements into a workable, practical training programme. The principal products of the development phase are the training materials that will be used by instructors and trainees.

4.1.4.1. Learning Activities (see Section 4.4.2)

One of the first steps in the development process is the identification of the specific trainee and instructor activities to be carried out to accomplish the learning objectives. This information is used to determine the duration of training programme modules and which instructional methods will be used, and to decide which training materials are needed.

4.1.4.2. Training Methods (see Section 4.4.3)

Closely related to the identification of learning activities is the selection of training methods. Training methods are the techniques or strategies employed to carry out the training process. Possible methods include lectures, demonstrations/practices with models/mock ups, discussions, walk-throughs, or self-study. Several different methods are possible in each training setting (classroom, simulator, laboratory/workshop, plant), and the selection of the best method depends on the specific learning objectives to be accomplished as well as on other factors.

4.1.4.3. Training Materials (see Section 4.4.4)

Technically correct and educationally sound training materials are the backbone of a good training programme. Information on the most frequently used training materials is given below.

Whenever possible, existing materials should be used as the starting point for materials development. It is practical and efficient for a utility to obtain training materials from other utilities having similar plants or to receive materials from reactor vendors or consultants. However, the materials should be checked prior to use to confirm applicability to the specific plant and to specific learning objectives. The materials should be amended, changed, or completely rewritten, as necessary.

<u>Written Materials</u>. Significant experience is required to develop written materials that transmit clear, accurate, and easily understood information to trainees. Written materials should contain practical examples, exercises, and necessary numerical data. Plant-specific information included in controlled documents and subject to change should be referenced rather than included in the written materials. Good written materials include illustrations and graphics to enhance the learning process. They should focus on the knowledge and skills required for the trainees' jobs and should not include unnecessary information.

<u>Audiovisual media</u>. A number of audiovisual media are used in training programmes, including films, videotapes, computer-based training, and video discs as well as slides and transparencies.

Models and mockups. Models are used to supplement classroom training, and mockups have proven valuable in developing some practical skills. Scale models with cutaway sections are used in training for some complex components. The most suitable models are those corresponding to specific plant components. Training on mockups is very common. Mockups are especially suitable for teaching some skills to craftsmen. For example, mockups are used to train quick entry into steam generators for tube inspections.

4.1.4.4. Lesson Plans (see Section 4.4.4.5)

Lesson plans identify the learning objectives, instructor and trainee activities, training methods, training equipment, and training materials to be used in a specific segment of the training programme, and provide guidance for their use. The effective use of lesson plans ensures consistent delivery of training from instructor to instructor and from course to course, and also ensures that all required knowledge and skills are covered. Lesson plans are used for all training settings, but differ significantly in format and content.

4.1.4.5. Materials Review and Improvement (see Section 4.4.5.)

A good training programme can be developed only if the most important materials are reviewed by experienced personnel (ex-trainees, instructors, experts in the applicable subjects and plant management) before they are used. During and after programme implementation, further improvements in materials should be effected using feedback from the trainees, instructors and supervisors.

4.1.5. Training Programme Implementation (see Section 4.5.)

The success of a training programme depends on the effectiveness of its implementation. There are a number of activities included in the implementation of a training programme.

4.1.5.1. Implementing the Training Plan

The training plan defined during the design phase should be elaborated to specify how the training process will be accomplished. This consists mainly of the following:

- Preparing implementing procedures
- Selecting and training instructors
- Securing the availability of trainees
- Securing the availability of training facilities and materials

Preparing the implementing procedures

The implementing procedures describe how training activities are to be performed and indicate the individuals responsible for those activities. The procedures may cover the following:

- Planning, developing, and scheduling training programmes
- Using training facilities
- Conducting training
- Administering tests
- Monitoring and assessing trainee performance
- Maintaining training records

A set of implementing procedures may apply to one or several training programmes.

Selecting and training instructors (see Section 4.5.2.)

Instructor qualifications should be compatible with the learning objectives. An instructor should be competent and experienced in the subject areas in which he conducts training; his experience should include actual power plant work in the area in which he will be teaching. In addition, a good instructor should have the ability to teach the knowledge and skills in a clear and understandable manner. He should command the respect of the trainees and possess interpersonal skills to be able to assess trainees' personality and attitudes. Instructors for each training programme should be selected and trained based on these considerations.

The performance of an instructor should be assessed on the basis of observation by a qualified evaluator, examination of the training materials that he develops, and evaluation of trainee accomplishment of learning objectives.

Securing the availability of trainees

The trainees assigned to training should be free of other duties. The selected trainees should possess the entry skills and knowledge required for the scheduled programme. The selection of the trainees should be effected sufficiently in advance to permit adjustment in training (remedial training) if required. The size of a group of trainees should be appropriate for the training setting and the intended learning activities. Class size should be limited, particularly for simulator and laboratory/workshop training.

Training language

A key condition for a well-implemented training process is a good understanding between the instructor and the trainees. In developing countries (and also in some industrialized countries which import major plant components) the training will often be conducted in a foreign language (in most cases, in the reactor vendor's language). The success of such training depends upon the instructors' ability to speak understandably to the trainees, the foreign language knowledge of the trainees, and/or the availability of capable translators. The selection and training of instructors and/or the selection and preparation of trainees should take these factors into consideration.

Securing the availability of training facilities and training materials

Before the start of a training programme, the training facilities and equipment should be available and in operable condition. The written materials, tools, visual aids, and consumables should be available prior to the time they will be used in the training programme.

The conduct of a successful training programme is dependent upon the availability of a suitable environment. The training should be conducted in facilities with sufficient space for trainees, instructors, and equipment, with good light, low external noise, few external interferences, and good heating, ventilation and air conditioning.

4.1.5.2. Implementation of Training (see Sections 4.5.3. to 4.5.9.)

After preparatory activities for the implementation of a training programme are completed, the training is ready to be conducted. The main activities associated with the conduct of training are:

- Pre-testing the trainees
- Preparing the instructors for training
- Delivering lessons
- Assessing trainee performance

Pre-testing the trainees

Pre-tests measure the trainees' entry level skills and knowledge. They indicate whether trainees possess the abilities to begin the training and identify course learning objectives that have already been mastered by the trainees.

The results of the pre-test allow a differentiation of the trainees to be made on the basis of their entry competence. It may be necessary to provide remedial training for those who do not meet the programme entry requirements or to permit accelerated training for those who exhibit mastery of specific learning objectives.

It is difficult to conduct successful training with a group of trainees with widely different background knowledge and skills. A group of potential trainees may need to be divided into two or more smaller groups with similar abilities, to permit the most effective and efficient training.

Preparing the instructors for training

Prior to beginning the programme, the instructors should prepare themselves to deliver the training. They should review the lesson plans to ensure familiarity with the content of the lectures, training material, equipment, tools, and media to be used in training. They should also verify the accuracy of the training material and determine whether training facilities are adequate for the number of trainees. They should ensure that the deficiencies discovered in training materials and training facilities are corrected in a timely manner.

Delivering lessons

Each lesson should be delivered in accordance with the lesson plan. Lesson plans should guide instruction conducted in all training settings - classroom, simulator, laboratory/workshop and on-the-job. To ensure effective training, the instructor has to stimulate the active interest of the trainees. This can be achieved by demonstrating the connection between the information given in a lesson with future duties and with learning objectives. The interest of the trainees can be enhanced if they actively participate in the learning process through discussions and solving practical problems.

The training courses should be scheduled at times of the day when trainees are fresh and disposed to learn and should be well-coordinated with the timing of other duties of the trainees. For example, morning training of night shift personnel should not be considered. The same holds for training courses immediately after or before working hours for full-time workers.

4.1.5.3. Assessment of Trainee Performance (see Section 4.5.10.)

The process for assessing trainees is selected and the instruments (tests, etc.) to be used are developed during the programme design and development phases. The essential part of trainee assessment consists of tests which are conducted periodically and at the end of the training process. The design of the training programme should define the knowledge and skills that need to be examined, the assessment methods, and the trainee success criteria and should include development of test items and tests.

In a well-implemented training programme, the assessment is not only effected by periodic tests and examinations, but also includes monitoring of the trainees' progress during the whole training period. This includes monitoring the trainees' attitudes, interest in improvement, specific skills, intelligence, motivation for career development, etc.

4.1.5.4. Training Records (see Section 4.5.11.)

Training records are an essential part of a properly implemented training programme. The records should contain all relevant data on the training programme as actually implemented (schedule, lesson plans, conduct of practical training, and examination questions).

Records of trainee assessment are a part of the training record. Each trainee's file should contain data on his/her performance (tests and examination data, and data on skills and knowledge acquired in training) and the instructors' assessments of the trainee's attitudes and competence.

4.1.6. Maintaining and Improving Training Programme Effectiveness (see Section 4.6.)

Every training programme is subject to evaluation which should determine to what degree the training meets its objectives. The evaluation process usually includes utility self-evaluation and evaluation by organizations serving a group of nuclear utilities. The results of the evaluations are used to make continuing improvements to training programmes.

4.1.6.1. Utility Evaluation of Training Programmes

The most interested and responsible party for the success of the training is the utility. The utility is also interested in obtaining objective evaluations of the training process. The primary measure of training effectiveness is the on-the-job performance of those who complete training. The evaluation process should identify and monitor indicators of that job performance.

Training evaluation must be an integral component of nuclear utility training. To be successful, the utility must develop the internal capability to evaluate training courses and training programmes.

Since training programmes are generally made up of courses which are conducted in phases, it is important to evaluate how well the phases are tied together (i.e. determine the existence of a logical sequence in knowledge and skill development from one phase to another).

Input from the following sources should be utilized for making improvements in the training programmes:

- Managers and supervisors observing the trainees' competence after completing training
- Training instructors
- Trainees (while in training)
- Trainees (after they are on the job)
- Training programme evaluator (an independent party from the utility staff or a consulting organization)
- Utility headquarters audit results

Training records also provide useful inputs for training programme evaluation. The records indicate the rate of improvement in skills and knowledge of the trainees (which can be determined from the results of tests and from instructors' observations).

It is important for a training programme promptly to incorporate changes reflecting modifications in plant systems, components, technical specifications, operating procedures and regulatory requirements. Equally important are the mechanisms for continual upgrading of training programmes to reflect lessons learned from utility operating experience. The evaluation process should include methods to identify these types of changes in training needs.

4.1.6.2. Evaluation of Training Programmes by Outside Organizations

As a supplement to its own evaluation, the utility can arrange for an independent, qualified group to conduct a training programme evaluation. It is, of course, of considerable value to the utility for the evaluation to be effected by its own staff, but an independent outside organization can sometimes identify weaknesses that are overlooked by the utility. An outside organization that is involved in evaluation at many nuclear power plant locations can provide an industry-wide perspective on current experience. The evaluation can be focused on training programmes for one or two specific plant positions or provide an assessment of the overall training process. An independent assessment of training programmes can also assure that all regulatory requirements relative to training programmes are satisfied.

There may be a tendency for either the plant or a training centre to have weaknesses and problems with their training activities. A regular audit by a utility headquarters expert team is invaluable for the identification of shortcomings in the continuing implementation of utility training policy. The utility may also receive input from the regulatory authorities on training programme weaknesses and problems. This input should be used in the utility's training programme evaluation system.

4.1.6.3. Correction of Identified Problems

The results of evaluations of training programme effectiveness should be analyzed to identify on a systematic basis the causes of any problems. Then action should be initiated to correct those problems. This system should also ensure that required improvements are accomplished.

4.1.7. Summary

- The first step in designing a performance-based training programme is to perform appropriate analysis, which involves identifying training needs and conducting job and task analyses for selected jobs. The analysis identifies required knowledge, skills, attitudes and performance standards for selected important tasks of the jobs.

- A performance-based training programme requires inclusion of quantified performance standards to be used in developing learning objectives and in assessing trainees.

- The development phase of a training programme expands the design by specifying the learning activities and the training methods, and includes the development of lesson plans and other training materials.

- In implementing the training programme, a number of items essential for successful training have to be accomplished: preparing implementation procedures; securing availability of trainees, training facilities, and training materials; pre-testing trainees; delivering lessons; assessing trainees; and maintaining training records.

- Evaluation of training programme effectiveness consists of several steps including internal utility evaluation and evaluation by an external organization. The evaluation is based on indicators of job performance and is supported by information and feedback from trainees, instructors, and job supervisors.

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4.2. DEFINING COMPETENCE REQUIREMENTS

4.2.1. Introduction

A training needs analysis (see Section 4.1.2.1.) establishes whether there is a need for a training programme or whether changes or additions to an existing training programme are required. The next step is to define the competence requirements associated with the job. The competence requirements for nuclear power plant personnel determine the standards and criteria to be used in personnel selection and in establishing the training objectives. Two types of competence requirements are defined:

- Entry qualifications for job candidates: required knowledge, skills and attitudes to enter training and aptitudes necessary to learn to fulfill job requirements successfully.

- Competence needed to perform the duties of the specified job/position.

Entry qualifications are usually prerequisites for selection of candidates for a position and for entering a specific training programme. The selection criteria for nuclear power plant operations personnel vary from country to country, especially the requirements for education and work experience.

The competence required to perform a specific job is determined from analysis of the job and its tasks and is the basis for the job's performance standards. The same data are used to determine training objectives in a performance-based training programme.

Although job competence requirements can be determined from analysis of the job, entry qualification requirements (education, experience, prior training) can be varied somewhat to accommodate the qualifications of available personnel. These variations in entry qualifications require variations in the content of the training programmes. Therefore, training programme design must be based on the known or required entry-level competence of trainees.

Specific competence requirements depend on plant design and plant organization. Plant design determines the operation and maintenance procedures and activities. Some aspects of plant design that influence competence requirements are: type of reactor, extent of automation, type and the number of components, equipment accessibility and maintenance requirements, plant layout, control room design, refuelling method, and condenser cooling (direct or cooling towers).

The responsibilities of individuals in the plant organization depend upon the organizational structure (lines of command and lines of communication). The plant organizational structure (including corresponding administrative procedures) defines the responsibilities of individuals and delineates the interfaces between functional areas. For control room staff and for shift personnel, the allocation of responsibilities and corresponding competence requirements are fairly standardized, but for support-function positions they are more plant-specific.

The formal entry qualification requirements for nuclear power plant personnel do not differ substantially from country to country. However, the actual knowledge and skills developed by the educational systems of various countries exhibit large differences. These differences are usually more pronounced in practical areas than in theoretical subjects. Therefore, even in the case of identical plants and identical job/task analysis for a particular job, the training and especially the practical training for that job may differ somewhat from country to country.

The remainder of this section discusses a systematic method for determining the specific competence required for a job commencing with a review of the knowledge, intellectual ability and skill requirements of the range of staff employed in nuclear power plants.

4.2.2. Knowledge, Intellectual Ability and Skill Requirements

Education and training programmes impart knowledge, intellectual ability, and manual skills and also develop communication skills.

In discussing the competence requirements of nuclear power plant personnel, it is useful to distinguish four levels of intellectual ability:

- Recall: the ability to recall factual information

- Comprehension: the ability to use knowledge by translating it into a different form, by interpreting it (summarizing, generalizing, inferring), and by extrapolating it (estimating and predicting on the basis of trends)

- Application: the ability to apply knowledge to new situations

- Evaluation: the ability to analyze, synthesize, and evaluate information and to derive new relationships and concepts

Manual skills involve the coordination of hand movements in response to information received through the eyes or other senses (e.g. welding, operating a control valve to maintain an instrument reading at a predetermined level).

Communication skills include the ability to transfer information to and from others, orally and in writing.

The three main types of nuclear power plant technical personnel (craftsmen, technicians and engineers) generally require an appropriate combination of knowledge, intellectual ability, and manual skills as shown in Table 4.2.-1. Requirements for communication skills generally increase as intellectual ability requirements increase.

4.2.3. Job Analysis and Task Selection

The first step in determining a job's competence requirements is to completely define that job. Job analysis is used to identify all of the tasks that are involved in performing the job and in determining the importance and difficulty of each task. This information is used to determine which tasks require training and which may require continuing training.

The selection of which tasks should be included in initial and continuing training programmes can be based on the application of criteria such as:

- Frequency of carrying out the task
- Degree of difficulty/complexity
- Implication of incorrect execution on plant safety
- Implication of incorrect execution on plant availability

TABLE 4.2.-1. KNOWLEDGE, INTELLECTUAL ABILITY and SKILL REQUIREMENTS FOR NUCLEAR POWER PLANT PERSONNEL

Craftsmen		
Scope of knowledge	-	limited
Level of knowledge	-	descriptive
Intellectual ability	-	predominantly recall
Manual skills	-	highly developed
Technicians		
Scope of knowledge	-	usually a limited scope of applied technology
Level of knowledge	-	in-depth, especially for higher-level of technicians
Intellectual ability	-	lower-level technicians: comprehension level and to a limited extent the application level
	-	higher-level technicians: the application level and to a limited extent the evaluation level
Manual skills	-	to understand the capability and limitations of craftsman techniques, but not to acquire craftsman skills; in some disciplines, technicians develop manual skills to a higher level than craftsmen
Engineers/Physicists/Chemists		
Scope of knowledge	-	a broad base of general science and technology
Level of knowledge	-	in-depth, especially in subjects of their specialisation
Intellectual ability	-	all levels up to evaluation
Manual skills	-	not usually developed

A complete description of a task includes three elements: the action to be taken or accomplished, the conditions under which that action is taken (plant conditions, tools or procedures available, etc.), and the standard of acceptable performance. The conditions and standards are determined during the task analysis process that is described in Section 4.2.4. The levels of intellectual ability required for task performance are indicated in Table 4.2.-2.

TABLE 4.2.-2. LEVELS OF INTELLECTUAL ABILITY REQUIRED FOR TASK PERFORMANCE

Type of Action	Level of Required Intellectual Ability
- Carry out specific action directed by supervisor or procedure	- Recall
- Take specific action when required by a condition or indication	- Comprehension
- Carry out multiple or complex actions when required by conditions (rule-based decisions)	- Application
- Independently decide on action to be taken based on diagnosis of a situation not previously encountered	- Evaluation

As described in Section 3.1.2., in defining tasks for a specific job, it is necessary to review relevant plant documents (equipment manuals; the safety analysis report; technical specifications; normal, abnormal and emergency operating procedures; the emergency plan; maintenance procedures; and plant administrative procedures). Identifying the tasks associated with a position also requires surveys and/or interviews with job incumbents and supervisors. The survey and interviews help determine the difficulty and importance of each task and the frequency with which each task is performed. This information is used to select which tasks should be included in the initial and continuing training programmes using criteria such as those given above.

An example of the Canadian (Ontario Hydro) approach to job analysis is given in Appendix F.

4.2.4. Task Analysis

After a position's tasks have been identified and appropriate tasks selected for inclusion in the training programme, those tasks should be analyzed. Such analysis is normally performed by specialists assisted by individuals experienced in performing the applicable job (subject matter experts). The output of task analysis is a list of the skills and knowledge required for proper performance of the tasks of that job/position.

Task analysis is a powerful tool to define not only the sum of knowledge and skills needed for a specific job but also to quantify the expected performance of the job incumbents. In practice, however, it is difficult to achieve this goal completely. The difficulty lies in performing job and task analysis for complex, non-repetitve tasks and particularly in determining performance standards for such tasks. Determining the competence requirements for jobs which involve intellectual tasks (control room operators, managerial positions, safety analysis, plant performance analysis, quality assurance activities, etc.) must rely on expert judgement as well as the results of job and task analysis.

Job and task analysis results are used to ensure that personnel are competent to perform all known, predictable tasks and to avoid improper operations due to lack of training or improper training. However, plant operation will always include the possibility of unknown or not previously experienced sequences (this is the reason for establishing technical support centres, the position of shift technical advisor, and diagnostic systems as operator aids), and these sequences include branches that depend on timely operator decisions. It is very difficult to analyze such tasks and to determine the corresponding performance standards.

The competence requirements for complex jobs must, therefore, be higher than the performance requirements derived from job and task analysis. The competence requirements for complex jobs must include not only the defined set of skills, knowledge, and attitudes but also intelligence and experience needed to deduce answers which were not explicitly learned during training. (This is sometimes called "diagnostic ability").

Tasks to be analyzed can be divided into two categories: routine tasks and complex tasks (such as, for example, tasks involving a search for defects, or abnormal and emergency operational conditions). The analysis of routine tasks with prescribed sequential steps (e.g., dismantling a component, calibrating an instrument, checking a reading, etc.) is simple and straightforward. Task analysis in such cases identifies action steps, their sequences, and corresponding performance standards.

The analysis of complex tasks is significantly more difficult and requires a different approach. Such tasks are not sequential and involve decisions at certain steps of the task. The analysis identifies stimulus-response patterns, performance problems involving decision points, and proper sequences.

The product of task analysis is a list of knowledge and skills which are needed to perform a job and which need to be developed through training. The Glossary in this Guidebook gives an example of the knowledge items and skills required for a tritium analysis task undertaken by a chemistry technician (in addition to a knowledge of/familiarity with the location and use of appropriate laboratory materials and equipment) (see the entries: 'task', 'knowledge' and 'skills').

Not only does the analysis of a task determine the areas in which knowledge or skills are required, but also the type of action required for the task indicates the level of intellectual ability required, as shown in Table 4.2.-2. Task analysis also identifies the manual skills that are needed, such as hand-eye coordination, arm strength, and balance. Required attitudes, such as cooperation (teamwork), vigilance, and good response under stress should also be identified.

4.2.5. Experience and Limitations in the Application of Job and Task Analysis

A number of difficulties have been encountered in the practical application of job and task analysis and the implementation of a systematic approach to training.

Positions for which job/task analysis is appropriate include the following:

- Non-licensed operator
- Reactor operator
- Senior reactor operator
- I&C technician

- Electrical maintenance technician
- Mechanical maintenance technician
- Radiological protection technician
- Chemistry technician
- Quality control technicians

The formal techniques of job and task analysis have long been known and have been used for repetitive jobs involving primarily manual skills. Such analysis has been applied less to intellectual, non-repetitive tasks and interpersonal skills (such as managerial and supervisory jobs). Recently, the application has been extended to advanced technologies (petrochemical, airlines, military, telecommunications, and nuclear power). The techniques must be modified somewhat in order to be used for complex and intellectual jobs (such as the reactor operator position). In addition, the process of establishing performance standards for such positions is not as straightforward as it is for repetitive jobs.

Experience has shown that job and task analysis is quite costly, labor-intensive, and time-consuming. Despite the selection of the most important tasks for analysis, the number of tasks per job may amount to several hundered, and the total number of tasks to be analyzed could reach a few thousand. A complete and comprehensive job and task analysis is a significant undertaking and requires experienced and talented people. The time necessary to perform an effective analysis can be easily underestimated, especially if the plant training staff and the plant support personnel do not have previous experience in such activities.

Despite the fact that the systematic approach to training is essential to develop performance-based training, many utilities (especially small ones) are reluctant to apply job and task analysis as the basis for training program development. This is generally regarded as shortsighted. With wrong or incomplete content, it does not matter how well the training may be performed; the trainees will still lack important knowledge and skills needed in their future duties.

A utility organization in a developing country introducing performance-based training should probably use the services of an experienced consultant to assist in performing the job and task analysis and developing the training programme. Additional problems which could be encountered by a developing country include the unavailability of qualified training instructors capable of implementing the training programmes. Without competent instructors to implement the training, a well-developed training programme would not significantly contribute to improvement in personnel performance.

4.2.6. General Employee Training

Properly conducted job and task analysis for nuclear power plant operations personnel will identify a range of knowledge and skills (also needed by contractors' staff) in the field of industrial safety and in the ability to respond correctly in the event of emergencies. This is usually referred to as general employee training. Those staff whose duties require them to work in radiation and/or contamination zones will also require initial training in the safe procedures they should follow when entering, working in and leaving these zones.

The degree of knowledge required in these subjects (industrial safety; fire protection; emergency response; health physics; plant design, organization and access procedures to non-radioactive parts of the plant) depends on the group to which the employees belong. This degree may be defined in terms of two categories:

Category 1: This knowledge enables a person, after a short introduction on site, to perform a task inside the nonradioactive part of the plant without having to be guided or supervised continuously. This knowledge may be attained for all of the above-mentioned subjects by short standard lecture or a corresponding film of about two hours.

Category 2: This knowledge enables a person to supervise others and to introduce them to their area of work. This knowledge may be obtained in the above-mentioned subjects by a lecture series totalling about five hours.

All employees need continuing training to maintain their competence in these topics (see Section 5.4.1.5.).

4.2.7. Summary

- The basic competence requirements for specific jobs in a nuclear power plant can be derived from job and task analysis. This analysis, together with the resulting performance standards, are the best sources of data on the competence needed by a job incumbent holding a specific job/position.

- Job and task analyses results are used to ensure that personnel are competent to perform all known predictable tasks and to avoid improper operations due to lack of training or improper training.

- Job and task analyses for complex and highly intellectual tasks - and determination of the corresponding performance standards - are difficult. The competence requirements for such jobs have to be higher than those derived from analysis because of the necessity to cope occasionally with unpredictable sequences of events.

- Some utilities confine job and task analysis to direct operating positions only, because of the importance of these positions and because there are no similar jobs in other industries.

- Job and task analysis is quite time-consuming, costly and requires experienced experts. This is the reason that some utilities are reluctant to base their training programmes on job and task analyses and continue to conduct traditional topic-based training. This approach is generally regarded as shortsighted, and neither efficient nor cost-effective in the medium /long term.

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4.3. DESIGNING A TRAINING PROGRAMME

4.3.1. Introduction

The design of a training programme includes a series of activities intended to develop learning objectives, tests, and other specifications of trainee performance based on job and tasks analysis results and on feedback from actual on-the-job experience. The subsequent development phase (as described in Section 4.4.) starts with the learning objectives produced during the design phase and develops the materials needed to conduct the programme. The design phase also includes the development of a training plan that guides the development phase of the training programme.

The first activities in designing a training programme are the establishment of performance standards and the selection of the most appropriate training environment (setting): classroom, laboratory, simulator, on-the-job, or self-study. These activities must precede the development of learning objectives and tests, the principal products of the design process.

4.3.2. Establishing Trainee Performance Standards

Early in the training programme design process, the standards for trainee performance should be established. These standards are linked directly to the standards for acceptable task performance identified during job and task analysis as described in Section 4.2. However, the trainee performance standards describe the level or accuracy of performance required of a trainee upon completion of training; these may be different from task performance standards, because the training and assessment environment may not be the same as the job environment, although it should be as similar as possible.

These explicitly identified trainee performance standards are the basis for developing learning objectives and for developing tests to assess trainees upon completion of training. They provide a direct link between the job requirements and the training programme. For the chemistry technician task (the example used in the Glossary under 'task') the trainee performance standard is also given under the entry 'performance standard' (note that successful performance is directly measurable with this standard).

4.3.3. Selecting the Training Setting

Before learning objectives and tests can be developed, the setting in which trainees will learn and demonstrate mastery of the required knowledge

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** Papers presented at the CSNI Specialist Meeting on Training of Nuclear Reactor Personnel: Orlando, Florida, 1987 and skills should be determined. The teaching of skills and demonstrations of performance should take place in the actual job environment or in a setting that has conditions and equipment similar to those on the job. Knowledge items can normally be more effectively learned and assessed outside of the job environment. However, selection of the training setting is not as straightforward as it would seem. There are usually several considerations which favor different settings, and selections are best made by experienced trainers.

The most commonly used training settings include the following:

- Classroom
- Laboratory or workshop
- On-the-job training
- Simulator
- Self-study

4.3.3.1. Selection of the Best Training Setting

Nuclear power plant operations require a broad range of knowledge and skills in a wide variety of subject areas to support the proper performance of assigned tasks. Although knowledge items and practical skills can be taught individually, actual task performance requires their coordinated and integrated application. Learning correctly to apply acquired knowledge and skills requires practice in situations that simulate work conditions. It is generally recognized that actual experience in performing a task is the best preparation for performing that task in the future. Practice under realistic conditions or a simulated work environment is the closest that a training programme can get to imparting work experience to trainees. Therefore, training of all nuclear power plant operations personnel should include such practice to the extent necessary to ensure that they can perform their work safely and reliably.

Selection of the most realistic training setting for all learning objectives is not always desirable, because a less expensive or less time-consuming setting can be used as effectively to accomplish many learning objectives. The selection of training setting could be affected by constraints related to the availability of training facilities and resources. By timely planning and allocation of the necessary resources this can be minimized. Particular attention should be given to:

- Timely availability of plant facilities.
- Procurement of a plant-specific simulator.
- Availability of laboratory facilities.
- Establishment of preferred training setting for the conduct of all training.
- Scheduling of trainees to ensure class sizes are optimized and are not too large.
- On-the-job training scheduled to take account of access opportunities provided by the plant operating regime.

The setting which is selected affects the degree of fidelity (accuracy in reproducing actual task conditions in the work environment) to which skills and knowledge can be trained. Selection of the training setting should consider the fidelity required for effective training. For this purpose, tasks can be divided into three categories:

<u>Tasks requiring complete replication</u> - Tasks in this group are the most important for plant safety and reliability and are the most complex to learn.

For this group of tasks, the plant or a full-scope replica control room simulator should be selected for training operating personnel. The types of operation most appropriately learned in full-scope simulators are described in Section 4.3.3.5. In the case of support personnel, formal on-the-job training or laboratory/workshop training in a setting simulating the actual job environment should be selected.

Tasks requiring less than full-scope replication - This group of tasks can be trained on part-task simulators or in laboratories or workshops in an environment not necessarily equivalent to the job environment.

Required skills and knowledge that can be grouped and taught independently of individual tasks - For these items, classroom or even self-study training may be selected. In many instances, this training will be preparation for training for the first two categories of tasks.

It has been found, particularly for initial training, that it is very beneficial to alternate between on-the-job, classroom, and simulator (or workshop/laboratory) training. For example, Appendix E shows the sequence of training for reactor operators in several countries. The characteristics, advantages, and disadvantages of the various training settings are described in the following sections.

4.3.3.2. Classroom Training

Classroom training is led by an instructor and includes the following:

- Lectures
- Demonstration of documents, drawings, models, photos, films, transparencies, etc.
- Discussions
- Solving problems under instructor supervision

Some advantages of classroom training are:

- Large quantities of information can be presented in a limited amount of time.
- Large groups of trainees can simultaneously participate in the training.
- It is less expensive and easier to organize them other forms of instruction.
- It does not interfere with plant operation or depend upon plant operational status during training.
- Favorable training environment can be easily secured (light, temperature, comfortable environment).
- Many training facilities and media can be efficiently used (overhead transparencies, slides, video, films, computer-aided training, models and small mockups).
- Simultaneous translation, if necessary, can be arranged for all trainees.
- Discussion with the instructor and between the trainees is facilitated.
- Written quizzes, tests, and examinations can be easily conducted.

In selecting classroom training as an appropriate training method, it should be recognized that this training also has some limitations:

- Classroom training does not reflect realistic job conditions.
- Hand-on skills cannot be developed or assessed.
- Classroom training is occasionally too theoretical and academic for the trainees to see a clear connection with job needs.

The best practice is to develop training programmes in which classroom training is combined with other training methods (laboratory, on-the-job, or simulator).

In a training programme, classroom training is typically divided into modules with specified numbers of contact hours. The modules are subdivided into units, each consisting of a defined set of lessons.

4.3.3.3. Laboratory and Workshop Training

Laboratory or workshop training is selected to provide a training environment that is not very different from the trainee's future job environment. Generally, laboratory/workshop training allows the following:

- Simulation of realistic job conditions with some degree of fidelity
- Learning actual skills required on the job
- Training to apply knowledge to solve realistic problems
- Supplementing classroom training with detailed knowledge and skills needed for component and system repair and maintenance
- Training in basic skills that support task performance

4.3.3.4. On-the-Job Training

The training programme for most nuclear power plant positions should include on-the-job training. On-the-job training is a systematic method of providing and ensuring that trainees obtain required job-related knowledge and skills in the actual work environment. Formal on-the-job training provides hands-on experience and allows the trainee to become familiar with plant routines while being trained. However, on-the-job training is <u>not</u> just working in the job/position under the supervision of a qualified individual; it involves the use of learning objectives, qualification guides, qualification standards, and trainee assessment. This training is usually conducted and evaluated in the work environment by qualified, designated individuals.

Some considerations in selecting on-the-job training as the training setting are:

- Assignment of trainees should be done in small groups.
- The training should be spread over a sufficiently long period of time.
- There should be no significant constraints (due to plant conditions) preventing accomplishment of the learning objectives.
- Many tasks should be actually performed during training while the number to be simulated should be limited.
- Qualified personnel should be available to conduct and supervise the training and to assess the performance of trainees.

4.3.3.5. Simulator Training

Simulators are the most sophisticated training facilities and are of particular value for effective and high fidelity training of control room personnel, because they permit interaction between operators and plant systems under actual, dynamic conditions. This is particularly true for plant-specific training simulators. (See Appendix G for a description of the various types of simulator and their uses). Training programmes utilizing simulator training include exercises corresponding to normal, abnormal, and emergency plant operating conditions and provide opportunities to gain valuable operating experience. In addition, simulator training provides a valuable opportunity to develop and assess operating team skills.

Simulators allow operators to learn control room activities in real time and in an environment very similar to the actual control room without interfering with plant operation.

Simulator training is indispensable for the control room staff.

The most important advantages of full-scope simulator training are its ability to:

- Demonstrate plant dynamics and system interactions.
- Develop diagnostic skills and to assess the performance of operators.
- Demonstrate and practice operator response to severe accidents.
- Achieve high fidelity in training (i.e., training conditions very similar to the actual job).
- Create realistic environment including stress during training and permit observation of trainees' performance in such situations.
- Train and assess teamwork (communication, coordination, cooperation, team management).
- Permit operators to experience/adapt to specific human factors features of the control room.
- Train in the use of (and to assess) procedures, especially procedures for dealing with incidents and accidents.

4.3.3.6. Self-Study Training

Self-study training (also referred to as self-paced or individualized instruction) is any training in which the trainees learn at their own pace without the continuous presence of an instructor. Self-study includes reading textbooks and other written training materials, individual research or problem-solving, computer-based instruction, and other similar techniques. Although continuous instructor supervision is not required, an instructor should be available to assist trainees and should periodically assess their progress.

Self-study training may be selected when sufficiently developed training materials and the nature of the subject to be learned allow such selection. Self-study is selected in most cases for fundamentals training, training on system or component descriptions, and as a supplement to classroom training.

If self-study is applied to skills training, there must be assurance that no danger exists for trainee injury or equipment damage and that meaningful training can be carried out without continuous instructor supervision. The tasks to which self-study may be applicable are of a simpler nature and do not require sophisticated and expensive facilities, components, or materials.

The assessment of trainee progress in self-study training is effected by tests after predetermined phases of training are completed.

4.3.4. Determining the Expected Trainee Entry Level

As described in Section 4.2.1., the expected entry level knowledge and skills of trainees entering a training programme must be determined in order to properly design that programme. The knowledge and skills that trainees are expected to possess are established as prerequisites for entering the training programme and need not be included in the training programme's learning objectives or materials. An accurate determination of trainee entry-level abilities helps ensure that the learning objectives are prepared at the appropriate level of difficulty: unnecessary training is avoided, and training begins at a level which permits trainees to complete the programme successfully.

The determination of expected trainee entry level abilities should be sufficiently specific to support the needs of the training programme's designers and developers. Specification of the required educational level of job candidates, while pertinent, is not sufficiently specific for these purposes. The expected knowledge and skills of trainees in the specific areas expected to be included in the programme are required. This type of information may be obtained by testing a representative group of potential candidates for the programme, but this may not be practical. In many cases, it is necessary to estimate the extent of trainee entry-level knowlege and skill in each area and later verify these estimates by pre-testing actual trainees prior to programme implementation (see Section 4.5.3.). In either case, the expected entry-level knowledge and skills of trainees should be documented in sufficient detail to support the development of learning objectives. It should be assured that that all members of a training group should meet the minimum prerequisite level of knowledge.

4.3.5. Preparing and Sequencing Learning Objectives

After training settings are determined and prerequisite knowledge and skills are established, learning objectives are developed for the tasks selected for training. Learning objectives describe what is to be learned in terms of measurable trainee performance. They ensure that training is linked directly to job performance requirements and define the content of the training programme.

A learning objective consists of three elements:

- A statement of the action that the trainee should perform.
- The conditions under which the action should take place.
- The standards of acceptable performance of the action.

There are two types of learning objective: terminal and enabling (see the Glossary entries for examples of enabling and terminal objectives). Terminal learning objectives are directly related to specific tasks and reflect the trainee performance requirements at the completion of training. Terminal learning objectives are developed for each task selected for training.

Enabling learning objectives describe trainee knowledge and skills that must be mastered before the terminal learning objective can be accomplished. Enabling learning objectives are developed for the knowledge items and skills identified during task analysis.

One enabling learning objective may be associated with several tasks and terminal learning objectives, and a large number of enabling learning objectives can be grouped together and taught prior to training on the associated terminal learning objectives. In developing enabling learning objectives, the expected entry-level abilities of the trainees must be known by the training programme designers. They fill the gap between trainee entry-level knowledge and skills and those required to master the terminal learning objectives.

After the training programme's terminal and enabling learning objectives are developed, they must be organized into a logical sequence for efficient learning. The following describes the general approach to sequencing learning objectives; however, the actual process involves many compromises and adjustments. First, the objectives are sorted and grouped by training setting. They are then sequenced to develop a training programme outline. Typically, the enabling learning objectives that can be learned in the classroom or in self-study are prerequisites to those that will be taught in the laboratory or simulator or in on-the-job training. There are two basic considerations in sequencing objectives:

- If the mastery of an item of knowledge or a skill depends on prior mastery of other knowledge or skills, the learning objective associated with that knowledge/skill should be taught after the mastery of those knowledge items/skills on which it is dependent

- For learning objectives that are independent, those which require higher levels of intellectual ability (application or evaluation) should be sequenced after learning objectives requiring lower levels (recall and comprehension).

The sequenced learning objectives are divided into modules dealing with similar topics taught in the same setting. After this step is completed, the training programme's content and structure are completely defined.

Examples of training programmes for operators and maintenance personnel of nuclear power plants in various IAEA Member States are given in Appendix H.

4.3.6. Developing Test Items and Constructing Tests

One of the last steps in the training design process is to construct the tests that will be used in the training programme. Tests may be written or oral examinations or practical demonstrations of acquired skills (in the case of on-the-job, laboratory, or simulator training). Plant walk-throughs are used in assessing operating personnel for modules dealing with the location or identification of systems and components. Performance demonstrations should involve actual performance of a task whenever practical, and simulated performance should take place under conditions that are as realistic as possible.

The assessment of operator knowledge and skills which cannot be assessed in the plant is performed by simulator exercises which allow trainees to demonstrate the ability to deal with normal, abnormal, and emergency plant conditions. In addition to assessing individual trainees, simulators are used to assess an operating team's ability to perform effectively as a team.

The training programme design should prescribe the assessment method for each module and for the final examination. For example, the training programme may prescribe the following for each module:

- Daily (or weekly) progress tests should be administered to evaluate the effectiveness of the training and to reinforce training for specific learning objectives where the trainees may have difficulties.
- Written or oral examinations will be scheduled at the end of each module.
- To successfully complete a module, the trainee must receive a final average grade of usually 70% or 80% or greater on the written or oral examination.

For each terminal learning objective, a performance demonstration should be developed which specifies how the trainee will demonstrate mastery. The job performance measure specifies the steps to be performed, the extent to which they will be actually performed or simulated, the setting in which they will be performed, and the standards for acceptable performance. For each enabling learning objective, several written and/or oral test items should be developed. If the knowledge and skill statements and learning objectives are well written, the development of test items is a relatively straightforward process. However, care must be taken to ensure that the test items require the level of knowledge, intellectual ability, or skill which is appropriate for job requirements.

The test items are used to construct trainee pre-tests, progress tests, and post-tests. Pre-tests measure actual entry-level abilities of trainees to determine whether they meet programme prerequisites or require remedial instruction. Pre-tests can also identify learning objectives that have already been mastered by trainees and can be eliminated from the training programme or can receive reduced emphasis.

Progress tests and post-tests are produced by using test items associated with the learning objectives that are included in each module of instruction. These tests should include questions associated with all of the learning objectives in the portion of the programme covered by the test. A post-test should be constructed for each module to determine whether trainees are prepared to go on to subsequent modules. Several progress tests may be needed for a module, depending on its length. (For example, daily or weekly progress tests may be appropriate for most classroom instruction). In constructing these tests, the number of test items associated with each learning objective and/or their point value should be based on the relative importance of the associated knowledge or skills.

4.3.7. Developing the Training Plan

A training plan is needed to guide the development and implementation phases of the training process for a specific job/position. The training plan specifies the programme's outline (a listing of modules, their content, contact hours, and sequence), settings for each module, schedule, testing requirements, and required facilities and equipment. The plan should be approved by utility management before programme development begins.

The plan includes responsibilities for programme design, development, implementation and approval. The responsibilities for training programme implementation should be divided between the training department staff and plant personnel. A typical split of responsibility could be as follows:

Responsibilities of the trainees' job supervisor:

- Evaluating individual candidates for intended training
- Specifying the training which each individual employee is required to complete for qualification
- Designating on-the-job trainers and evaluators
- Reviewing the training programme content

Responsibilities of the training supervisor:

- Review, administer, design, develop, schedule and implement training programme.
- Approve lesson plans, laboratory guides, self-study guides, qualification checklists.
- Coordinate programme scheduling.
- Organize the provision of the necessary training material and training facilities.
- Provide assistance to trainees and designated on-the-job trainers/evaluators.
- Provide and perform classroom and simulator instruction and examination preparation and administration.

The training plan specifies required trainee entry qualifications for the programme and for each training module, the methods of trainee assessment during and after completion of each module, and performance criteria (for example, required grades on written and oral examinations).

A trainee would normally not be allowed to begin the programme if he does not meet the established prerequisite entry requirements and should not be allowed to begin a module until he successfully completes prior modules.

In addition, the training plan should prescribe the action to be taken if a trainee fails to meet expected performance standards. Two possible alternative actions, for example, may be:

- If a trainee fails to meet training performance standards, remedial training is suggested as a course of action. The trainee should be assigned to self-study or tutoring as directed by the training supervisor. Re-examination will be administered as soon as practical upon completion of the remedial training. Failure to meet the standards after remedial training should require the training supervisor and the trainee's supervisor to meet and examine jointly the individual's performance and determine what action should be taken.

- If a trainee fails to meet the established performance standards of any module, the training supervisor should meet with the trainee's job supervisor to evaluate that individual's potential to complete the training programme successfully and to perform the duties and responsibilities of the position for which he is being trained. If it is decided to retain the individual in the programme, additional instruction should be provided so that the individual meets the performance standards. A re-examination should be conducted to verify the individual's competency to continue.

The training plan should also prescribe the training records to be maintained. For example:

- Schedule of the training programme as it was actually conducted.
- Lesson plans.
- Lecture attendance records.
- Examinations and examination grades for each module.
- Final qualification certification for trainees.

4.3.8. Summary

- The activities of training programme design are essential for the training programme to be closely focussed on the knowledge and skill requirements of the job.

- Trainee performance standards are established and are used to develop the learning objectives and tests for the training programme.

- Selecting the appropriate training setting for conducting the training and assessing trainee performance (classroom, laboratory, on-the-job, simulator, or self-study) involves consideration of the relative advantages and disadvantages of each setting and of a number of constraints related to resources and facilities.

- Classroom training is very efficient for developing knowledge, but it must be supplemented to develop hands-on skills and teamwork; laboratory, simulator, and on-the-job training are best for developing job skills, but are costly to conduct and can accommodate a limited number of trainees; and self-study is inexpensive but can only be used for a very limited number of learning objectives.

- Expected entry-level knowledge and skills of trainees (which later become required prerequisites for entrance to the training programme) must be determined before the training programme content can be defined.

- Terminal learning objectives must be developed for each task that has been selected to be included in the training programme; enabling learning objectives are developed for the knowledge and skills identified during task analysis and fill the gap between trainee entry-level abilities and those required for accomplishment of the terminal learning objectives.

- The learning objectives are to be organized in a sequence that permits efficient trainee learning.

- Test items and tests are developed for use in assessing trainees before, during, and after the training programme is completed.

- A training plan is developed after other design activities are completed, to guide the development and implementation of the training programme.

4.4. DEVELOPING A TRAINING PROGRAMME

4.4.1. Introduction

The training programme development process produces the training materials needed to support the implementation of the training programme. Examples of training documents produced in the development phase are given in Appendix J. Inputs to the development process are the learning objectives, trainee performance standards, tests and the plan for providing training, all of which have been produced during the design phase. Development begins with identification of the learning activities necessary to accomplish the objectives and the training methods to be used. The learning activities and methods that are selected determine the materials needed for effective training, (e.g., written materials, models, computer-based training software). During implementation, the training is provided by instructors using lesson plans which are also prepared during this phase.

4.4.2. Specifying Learning Activities

In the first activity of training programme development, the structure of training is established, based on the sequence selected during the training design process. The achievement of effective and efficient learning requires training whose structure is based on how people learn.

Various strategies exist for the sequencing of instruction. One approach for the instructional events associated with three defined components of a lesson is as follows:

Lesson Component		Instructional Event
Introduction	-	Gaining and Maintaining attention and motivating the trainee

	-	Communicating the learning objectives
	-	Cueing recall of prerequisite knowledge
Development	-	Presenting the training material
	-	Providing learning guidance
	-	Eliciting mastery of the learning objectives
Review	-	Evaluating trainee performance
	-	Providing performance feedback
	-	Enhancing retention of training material

For any learning objective (or group of learning objectives) the trainee progresses through the nine events. In determining the strategy for a training session, the instructor must decide how to provide for each instructional event, e.g., how is the content to be presented? How will feedback be obtained? Thus, from each of the nine events, appropriate instructor and trainee activities can be established to meet the learning objective(s).

This information is used to determine the duration of training programme modules, to determine which training methods will be used, and to decide what training materials are needed.

4.4.3. Selecting the Training Methods

Training methods are the techniques or strategies used by the instructor to enhance the learning process. They include lectures, demonstrations/practices, discussions, oral questioning, role playing, walk-throughs and self-pacing.

The training setting that has been chosen on the basis of the learning objectives in the design phase will largely determine which of the training methods can be adopted. Although such methods as discussions and oral questioning have a very general application in all settings, other methods are only applicable in certain settings. Preferred training methods for each training setting are given in Table 4.4.-1.

4.4.4. Developing Training Materials

Training materials include all printed documents, equipment, computer software and audiovisual media used in conducting training. Examples of training materials include textbooks, trainee handouts, system descriptions and diagrams, transparencies, models, simulators, qualification guides, lesson plans etc.

In the development phase of a training programme, materials appropriate to the training setting selected in the design phase (see Section 4.3.3.) are produced. This process depends on decisions as to the training method to be utilised (i.e., lectures, discussions and oral questioning are all aspects of the classroom training method).

TABLE 4.4.-1. PREFERRED TRAINING METHODS FOR EACH TRAINING SETTING

	Classroom	Laboratory/ Workshop	OJT	Simulator	Self-Study
Lecture	x				
Demonstration/ Practice		x	x	x	
Discussion	x	x	x	x	
Oral Questioning	x	x	x	x	
Role Playing		x	x	x	
Walk-Through		x	x	x	
Self-Pacing			x		x

Some media are more effective than others in a particular training setting and hence the setting chosen in the design phase will be a major factor in establishing media alternatives. A matrix setting out possible alternatives for each setting is given in Table 4.4.-2.

Training materials and media for the chosen setting should support the learning activities and be designed to be relevant and effective.

The development of new training materials requires considerable skill and is both time-consuming and costly. Hence, the contribution which might be made by existing training materials should be established before committing resources to developing new materials. The adoption or modification of existing material will help to minimise training costs.

In this context a primary source of materials are past and existing training programmes. Suitable programmes may be found from or through the nuclear power plant vendor, who could have supplied an identical or a similar plant to another utility, or direct from another utility.

In selecting and reviewing existing training materials, the evaluation must be undertaken by competent instructors with the necessary subject matter expertise and should take into account the expected trainee entry level, identified learning objectives, proposed learning activities and training plan produced in the design phase.

In some instances existing materials can be used without further modification. However, modification should be undertaken when the existing materials are incomplete or require minor changes. At some point the extent of change necessary will justify the production of new materials.

4.4.4.1. Written Materials

Written materials utilised by trainees during a training programme will normally be either textbooks or handouts. Textbooks are rarely totally satisfactory as a means of mastering learning objectives. Invariably they

TABLE 4.4.-2. MEDIA ALTERNATIVES BY TRAINING SETTING

	Classroom	Laboratory/ Workshop	OJT	Simulator	Self-Study
Simulation	x	x	x	x	x
Computer-Based Training*	x			x	x
Film/Videotape/Videodisc	x	x			x
Slide/film strip with sound	x	x			x
Audiotape	x	x			x
Slide/film strip without sound	x	x			
Transparencies	x	x			
Models and Mockups	x	x	x		x

* France makes use of computer-based training in all training settings.

will contain irrelevant or superfluous information, and they may not be easily obtained in some developing countries. They will, however, provide a useful source of information for those involved in the development of training materials and particularly in support of theoretical topics such as reactor physics and thermodynamics. Rarely will it be appropriate to develop a textbook in support of a training programme. Textbooks can be useful as references in support of trainee handouts as a means of providing complementary and supplementary information to be used in the reinforcement of learning.

In general, it will be found more effective and efficient for written materials to be produced in support of a series of learning objectives to be covered in a single training session. Such materials should be developed using guidelines intended to promote efficient learning. Possible guidelines include the following:

- Formatting should ensure easy trainee use. For example, charts, graphs, tables and other illustrations emphasising key points should be located on separate pages and in close proximity to the related information in the material.
- The reading level of training materials should be consistent with the expected entry level skills of the trainees.
- Learning objectives should be provided to trainees as part of written training materials.
- The material should be clear, accurate and concise.

- In general, essential information should be located in the materials, and the trainees should not be referred to other places for that information. However, training materials should not repeat or include plant-specific information that is included in controlled plant documents and is subject to change, but should contain references to those plant documents.

- The training materials should refer to the job for which the trainees are being trained by describing that job environment, how the information will be applied to the job, and why it is important for the trainee to learn that information.

- Transparencies and slides are commonly used to supplement instructor explanations. Copies of them should be included as part of the written material available to the trainees. There should be a close connection between the information transmitted by transparencies and the explanations of that information in the text.

4.4.4.2. Audiovisual Media

As previously stated, a variety of audiovisual media are available including films, videotapes/videodiscs, computer-based training as well as slides and transparencies. Those media involving visual movement, e.g., videos, are frequently used to illustrate specific plant activities such as refuelling, maintenance, transport of heavy components etc. The videodisc has the benefit of permitting a very fast search for specific sequences and is often integrated with computer-based training for self-paced study. However, the necessary hardware and software is currently quite expensive.

The advantage of using films and videotapes/videodiscs is the ability to transmit information to trainees which would otherwise be difficult to describe by oral presentation, slides or texts. To maximise their benefit the instructor will need to integrate them into a structured lesson.

Choice of media

The choice of media should be considered in terms of availability of the technology, cost and practicability of use in the training programme. Factors to be considered in this evaluation include:

- The projected life-cycle costs of the selected media are lower than other equally useful media.

- Budgetary resources are available, particularly if the media requires a substantial capital investment.

- The media are appropriate for the number of trainees who will be trained at a given time.

- The media are appropriate for training that is subject to frequent change or is conducted infrequently (if applicable).

- The lead time to produce the materials is compatible with the timescale for implementation of the training.

4.4.4.3. Computer-Based Training

The purpose of computer-based training is to provide continual and consistent training for personnel. The combination of classroom lessons and self-paced, individualized instruction permits training at times convenient to the trainees' work schedules. Computer-based training can ensure student understanding, since it can be designed to require correct answers to questions that demonstrate understanding prior to allowing the trainee to proceed to the next section of the course.

Computer-based training utilises a computer terminal, computer, and the necessary software to present the training programme without requiring the continuing presence of the instructor, although an instructor should be periodically available to assist trainees. This method can offer some advantages over other media and a classroom training setting, for example:

- The training can be adjusted to individuals' schedules, independent of the availability of instructors and other trainees' schedules.

- A trainee can adjust the training duration (including repetitions of some sections) to his ability to fully understand the presented material.

- In many instances, the more efficient use of training time allows shortening of the duration of individual courses and so reduces training costs.

- Instructors have more time available to help trainees with the most difficult parts of the training programme by being freed from the necessity to lecture the whole course.

- Computer-based training software can be designed to include testing programmes which include automatic scoring and record keeping.

Despite these advantages, however, computer-based training is limited in its applicability because of the high development costs, the limited subject matter that is appropriate, and the small number of trainees to be trained in many subjects (especially plant-specific subjects). It may be appropriate and cost-effective for repetitive training when no changes in content are anticipated and large numbers of trainees are to be trained individually or in small groups.

Appendix K presents a comparison (Czechoslovakia) between the retention of knowledge after 8 weeks when the trainees have received instruction through classroom lectures or through computer-based training, together with an example of the content of a computer-based training programme.

4.4.4.4. Models and Mockups

Scale models are often used in training and as such are helpful in learning the characteristics of major plant components. Usually they either have a cutaway section to help in visualising the internal parts of the component or they can be disassembled to reveal them.

The following models might be used as training aids in support of classroom training sessions.

- Nuclear steam supply system
- Reactor vessel cutaway
- Reactor coolant pump seal
- Steam generator (PWR)
- Fuel assembly
- Control rod drive mechanism

Mockups which are full-scale sections or assemblies are especially suitable for teaching some of the skills required by craftsmen. They permit rehearsal of an operation or procedure until competence has been achieved. Activities to be conducted in radiation zones can be practised and hence the exposure time minimised. A mockup in common use is the end of a steam generator incorporating the correct access geometry such that entry to conduct tube inspections can be practised.

4.4.4.5. Lesson Plans

In the development stage of the training programme, the most important documents specifying the training activities are the lesson plans. They are used by the instructor to guide the learning process and to outline instructor and trainee activities.

Lesson plans identify the learning objectives, learning activities, training equipment and training materials needed for training and provide guidance for their use. As such they are the controlling documents for utilising all other training materials. They are important in ensuring consistency in delivering lessons between several training instructors and from one class to another. They are necessary whatever the training setting (classroom, laboratory, OJT, workshop, simulator) and should be prepared to reflect the specific characteristics of these settings and for the tasks they support.

Many sections of the lesson plans will have common headings independent of the training setting. Table 4.4.-3. demonstrates this point and shows where differences arise within typical lesson plans for the classroom, simulator and OJT.

TABLE 4.4.-3. TYPICAL LESSON PLAN CONTENT

1. Training description

   - Title, purpose and scope of training
   - Terminal objective(s)
   - Duration of training
   - References for additional instructor research

2. Expected trainee entry-level skills and knowledge

Classroom	Simulator	OJT
3. Presentation outline	3. Exercise guide	3. Formal OJT guide
- Enabling objectives	- Enabling objectives	- Enabling objectives
- Learning activities	- Learning activities	- Learning activities
- Training methods	- Training methods	- Training methods and use

TABLE 4.4.-3. (continued)

- Text material and reference assignments	- Reference assignments	- Equipment schedule
- Audiovisual scheduling and use	- Initial plant conditions including plant state	- Safety considerations
- Trainee handouts assignments	- Materials and references	- Reference
- Trainee study assignments	- Instructor actions	
	- Correct operator response	
	- Malfunctions available for use in exercise	
	- Plant conditions expected at end of exercise	

Classroom Workbook Assignments
(if applicable)

- Schedule and application
- Questions or projects for completion by trainee
- References available to trainee
- Safety considerations

4. Progress test and post-test administration

   - Scheduling and use
   - Training standards for evaluating trainee performance
   - Instructions for providing feedback to the trainees

Examples of lesson plans for conducting training sessions in classroom, laboratory and simulator settings are included in Appendix J.

In the case of a simulator exercise, it is essential that the lesson plan contains sufficient information on how to operate the simulator and the establishment of a pre-programmed exercise scenario (if appropriate) and the types of malfunctions and the sequence, method and timing of their insertion. All such exercises should be prepared in advance and run through so as to check for satisfactory simulator performance. Hence, the ability to implement a simulator exercise will have been thoroughly tested using the lesson plan prior to implementation. An example of a simulator exercise guide is given in

Appendix J.1. The standards and objectives of simulator lesson plans should receive the concurrence of the trainees' plant functional manager. The simulator, as in the case of the plant, must be operated in accordance with formal directions provided by the plant operations manager. Simulator lesson plans must reflect and reinforce the operating philosophy and standards of the nuclear power plant.

4.4.4.6. On-the-Job Training Materials

Experience of IAEA Operational Safety Review Team Missions has been that the implementation of on-the-job training (OJT) in many utilities has been inferior to the standards achieved in other training settings. For OJT to be effective a number of steps must be taken into account when developing the materials. While many of these follow from the earlier parts of this section, they are explicitly stated below in view of the significance of OJT in achieving staff competent to operate a specific plant with its own particular systems and layout.

- Learning objectives must be defined and known to the trainees, trainer and assessor.

- The performance standards to be demonstrated for successful completion of OJT must be defined.

- The OJT guide should reference materials that the trainee can use in training.

- OJT can relate to a number of similar tasks, e.g., operation of a commonly found type of flow control valve. Such tasks can be grouped and trained jointly.

A sample OJT lesson plan is included in Appendix J.2.

4.4.5. <u>Evaluating Training Materials</u>

Design and development activities produce the materials to be used during training. It is essential that these materials be evaluated so that faults can be corrected and improvements made to increase the effectiveness of these training materials.

Three activities provide feedback data which identify any need to revise the training materials:

- Technical review

- Evaluation using a small group of trainees

- First run of the course

<u>Technical Review</u>

The goal of the technical review is to ensure the training materials are technically accurate, current and consistent with plant systems, equipment and procedures. The review must be undertaken by an expert who provides feedback to the programme developer. Lesson plans, text material, trainee handouts and workbooks, audiovisual media and test items should be reviewed and deficiencies identified for analysis and correction. Although the process ensures technical accuracy, the activities described in the next two sections are necessary in order to determine training effectiveness.

Small Group Evaluation

After revisions from the technical review have been made, a tryout of the training materials should be conducted on a small group of trainees who possess the entry level skills and knowledge expected of future trainees. During the tryout, the training setting is simulated as closely as practical. The training materials are presented and all tests are administered and scored. Data is collected for subsequent analysis and is used to improve lesson plans, text material etc as in the technical review.

It should be recognised that a small group evaluation may not always be feasible, particularly with courses of lengthy duration. An alternative is to conduct small group evaluations on the most important sections of the course. Courses or sections of courses not submitted to small group evaluation should receive increased monitoring during the first run.

Conduct First Run

During the first run of the course, the materials (which may have been revised as a consequence of the small group evaluation) are subjected to a further phase of training programme evaluation.

In addition to training the first group of trainees, the first run determines the usability of the training materials under intended conditions and confirms the revisions made to the materials during the technical review and small group evaluation. The course material should still be considered to be in a tryout phase; hence, training management should monitor the process closely, providing additional assistance to the instructor when needed.

Provision and Evaluation of Feedback Data

All data collected during the technical review, small group evaluation and first run should be reviewed to determine the need for revisions to the training materials. Technical inaccuracies should principally be found through the technical review process.

Results from the tests conducted in the small group evaluation and first run are valuable in determining the extent to which the training achieves the intended learning outcomes. Failure of the trainees to achieve satisfactory test results may necessitate revision of the training materials. However, in the event of low scores, care must be taken to check that the test items do relate to the job-related knowledge and skills and hence to the training materials used in the lessons. Completion of post-training questionnaires by the trainees, supplemented by oral interviews, should be used to provide data on training programme difficulty, length, clarity, terminology, pace and structure.

Further information on methods of obtaining feedback for training programme evaluation is contained in Sections 4.5.10.2. and 4.6.

4.4.6. Summary

- Training sessions should be designed to take into account the latest knowledge of how people learn. This enables instructor and trainee activities to be established to meet defined learning objectives. Guides for the conduct of OJT are particularly important in view of the industry-wide weaknesses found in this aspect of training.

- Various training methods can be used by an instructor to enhance the learning process. They include lectures, demonstrations/practices, discussions, oral questioning, role playing, walk-throughs and self-pacing. The options available to an instructor are largely determined by the choice of training setting.

- Modern training techniques use a variety of media in the training process, including simulations, computer-based training, films, videotapes, videodiscs, slides, filmstrips, audiotapes and transparencies.

- Audiovisual media are beneficial to the learning process, when properly integrated into a structured lesson. In addition to the static media of slides and transparancies, in some circumstances those involving movement such as films and videos transmit information more satisfactorily, e.g., on maintenance and refuelling activities.

- Computer-based training has advantages in terms of portability and flexibility in delivering self-paced instruction including tests. However, it is expensive if the numbers using it are small or the material needs revision from time to time.

- Well-prepared training materials are essential to the successful implementation of a training programme. They include textbooks, handouts, system diagrams, transparencies, models, simulators and lesson plans.

- Textbooks are useful reference sources, particularly for staff involved in the development of written training materials. For trainees, standard text books will invariably contain a certain amount of irrelevant information.

- Handouts for trainees should be formatted for easy use, relate to the series of learning objectives covered in a single training session and be developed using guidelines intended to promote efficient learning.

- Scale models of certain plant components are helpful in support of classroom training sessions. Full-scale mockups enable procedures to be rehearsed until competency is achieved and are particularly useful for rehearsing operations to be conducted in high radiation zones.

- Lesson plans are essential controlling documents for guiding the learning process and for outlining instructor and trainee activities. They should be produced for all training settings - classroom, workshop, laboratory, OJT and simulator.

- The production of new training materials is costly and hence, where possible, existing training materials should be obtained and reviewed for suitability. Reactor vendors and utilities operating identical or similar plants are useful sources of materials.

- Training materials should be reviewed for technical accuracy and effectiveness in meeting the learning objectives. The latter can be achieved through presentation of the material to a small group of relevant trainees and from data obtained from the first run of the course.

- Review of existing training materials should be undertaken by instructors who are subject matter experts and should take into account the expected trainee entry level, identified learning objectives, proposed learning activities and training plan produced in the design phase. At some point the extent of change necessary to existing training materials will justify the production of new materials.

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4.5. IMPLEMENTING TRAINING AND ASSESSING TRAINEE PERFORMANCE

4.5.1. Introduction

Training implementation is the set of activities that develop in the trainees the skills and knowledge needed to perform the tasks that make up the job for which they are being prepared.

The effective and efficient implementation of the training plan is based on the use of properly developed training materials, the availability of qualified instructors and the availability of trainees with prescribed prerequisite skills and knowledge. In addition, it is important to secure adequate training facilities.

In preparing to implement training, it is also highly desirable to establish conditions which allow maximum attention by the trainees to the training process. This can be achieved by releasing the trainees from all job duties while in training and by selecting a suitable time for the training sessions. Training held late in the evenings, on weekends and during vacation periods will be less efficient and effective than training during normal working hours.

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* Papers presented at the Seventh Symposium on Training of Nuclear Facility Personnel, Orlando, Florida 1987.

** Paper presented at the CSNI Specialist Meeting on Training of Nuclear Reactor Personnel, Orlando, Florida 1987.

The efficiency and effectiveness of the training also depend on the availability of a suitable training environment. The training facilities must be satisfactory for the group of trainees being trained. There must be sufficient light, adequate heating, cooling and ventilation facilities, and very little outside disturbances. It helps also if some recreation and refreshment facilities for trainees are available in the vicinity of the training area.

There are four distinct activities in the conduct of training:

- Preparing the instructors.

- Pre-testing the trainees.

- Delivering the lessons (or conducting simulator, laboratory or on-the-job training).

- Assessing trainee performance.

This chapter describes the conduct of classroom, on-the-job, laboratory/workshop, simulator, and self-study training.

4.5.2. Developing Competent Instructors

The efficiency of nuclear operations personnel training is strongly dependent on the availability of competent instructors. Instructors must understand thoroughly all aspects of the subjects being taught and the relationship of the subject to nuclear plant operation. Hence, it is preferable for an instructor to have held a post at a nuclear power plant relevant to his field of instructional responsibility. For example, a simulator instructor should have held a shift operations post at an appropriate level of seniority in a plant of the same design. It can be beneficial for the instructors in the training organisation to be a mix of permanent and seconded staff. The secondees should be from nuclear power plants and bring up-to-date experience into the training function which provides feedback to the training programme and also aids credibility, particularly with staff undergoing continuing training. All instructors must have the skills and knowledge needed to employ instructional methods and techniques that enhance learning and successful job performance.

4.5.2.1. Instructor Qualification

Utility management should establish technical and instructional qualification criteria, procedures, and programmes for selecting, training and certifying qualified instructors.

The selection criteria for instructors should include required technical skills and knowledge, and instructional qualifications, attitudes and communication skills.

The technical competence of training instructors includes theoretical knowledge, practical skills and work experience in the subject area in which they conduct training and/or in the job for which they train personnel.

Instructor technical competence requirements depend on two factors:

- The subjects being presented.

- The positions of trainees being instructed.

Suggested instructor competence requirements based on the job of the trainees and the subjects being taught are given in Table 4.5.-1.

Not only must simulator instructors have experience of relevant nuclear power plant operations, they must also have training in the operation of the simulator. This must be undertaken from the point of view both of the trainee using it and also of the instructor. The instructor must learn to operate the simulator (initialise, freeze, snapshot etc), to inject malfunctions, to understand the boundaries of validity of the simulator and to operate any facilities used in support of the training session, e.g., video cameras and recording equipment. Unique aspects associated with simulator training which need to be included in the instructor training programme are those relevant to:

- Development of diagnostic skills.

- Team work within the shift team.

- Introduction and management of stress on the trainee(s).

4.5.2.2. Establishing Instructional Competence

Most instructors achieve the required instructional competence by completing a specific training programme. Both initial and continuing training are needed to establish and maintain instructors' competence.

The systematic development of an instructor's skills is facilitated if training is carried out in steps. Typically, the first step is described as fundamentals of instruction and is a prerequisite for conducting classroom training. The more advanced training is completed before implementing and supervising laboratory and simulator training. Instructors for on-the-job training are typically qualified incumbents, not full-time instructors, who receive training in how to conduct this type of training.

Learning objectives associated with fundamentals of instruction relate to the following tasks:

- Role of the instructor.
- Arranging the classroom (or other instructional setting) to fit the training sessions.
- Understanding how adults learn.
- Using appropriate training techniques.
- Using lesson plans and other instructional materials and media.
- Conducting lectures.
- Conducting discussions.
- Conducting practical demonstrations.
- Assisting trainees in solving learning problems.
- Assessing trainees.
- Maintaining and using individual student records and programme records.

An example of a learning objective of fundamental instructional training might be as follows:

Example: Learning objective - fundamental instructor training.
Given a prepared lesson plan, instructional material and media, the instructor trainee should be able to deliver an appropriate lesson. This lesson should be consistent with the content covered in the training programme, and the instructional techniques should be appropriate for the setting, the use of the selected media and the intended trainees.

TABLE 4.5.-1. SUGGESTED INSTRUCTOR TECHNICAL COMPETENCE

IF THE TRAINEES ARE:	AND THE SUBJECTS BEING TAUGHT ARE:	THEN THE INSTRUCTOR'S TECHNICAL QUALIFICATIONS SHOULD BE:
Reactor Operators (ROs) or Senior Reactor Operators (SROs), or Shift Technical Advisors (STAs), or Engineers, or Technical Managers	Academic Subjects including: . Mathematics . Chemistry . Physics . Reactor Physics . Materials . Thermodynamics . Heat tranfer . Fluid Mechanics . Electrical science . Process control principles . Health physics . Reactor plant materials	- Successful completion of training/education in subjects being taught, at or above the level to be achieved by the trainees, and - It is preferred that the instructor have a bachelor's degree in engineering or a related science that includes courses in the subjects being taught
	Generic nuclear power plant technology including: . Reactor control and operating characteristics . Radiation protection and control . Chemistry control . Reactor plant instruments and controls	- SRO license for a plant of the same type as the trainees' plant (same NSSS vendor), or - Successful completion of SRO training including simulator certification at the SRO level for a plant of the same type as the trainees' plant
	Plant-specific systems, operations, transient response, and procedures required for plant safety (other than simulator training)	- SRO licence for the trainees' plant or similar plant (same NSSS vendor and similar plant safety-related systems), or - Successful completion of simulator certification at the SRO level for the trainees' plant or a similar plant

TABLE 4.5.-1. (continued)

IF THE TRAINEES ARE:	AND THE SUBJECTS BEING TAUGHT ARE:	THEN THE INSTRUCTOR'S TECHNICAL QUALIFICATIONS SHOULD BE:
Reactor Operators (ROs) <u>or</u> Senior Reactor Operators (SROs) <u>or</u> Shift Technical Advisors (STAs), <u>or</u> Engineers, <u>or</u> Technical Managers	Simulator training: . Systems . Operations . Transient response . Procedures	- SRO license for the plant corresponding to the simulator or a similar plant, <u>or</u> - Successful completion of simulator certification at the SRO level for the trainees' plant or a similar plant
Non-Licensed Operators	Power plant fundamentals including: . Applied electrical, mechanical, chemical, I&C, and nuclear fundamentals . Equipment and component descriptions and principles of operations Plant-specific technology including: . Procedures and operating practices . Plant systems and components . Practical factor demonstrations	- RO license, <u>or</u> - Demonstrated knowledge and skills in the subject being taught, at or above the level to be achieved by the trainees, as evidenced by previous training/education
Technicians, <u>or</u> Maintenance Personnel	Nuclear power plant technology (for trainees' plant or a similar plant) including: . Principles of plant operation . Plant systems and components	- Demonstrated knowledge and skills in the subjects being taught, at or above the level to be achieved by the trainees, as evidenced by previous training/education and through job performance

TABLE 4.5.-1. (continued)

IF THE TRAINEES ARE:	AND THE SUBJECTS BEING TAUGHT ARE:	THEN THE INSTRUCTOR'S TECHNICAL QUALIFICATIONS SHOULD BE:
Instrumentation and Control Technicians	Principles of process instruments and controls including electronics, pneumatics, hydraulics	- Demonstrated knowledge and skills in the subjects being taught, at or above the level to be achieved by the trainees, as evidenced by previous training/education and through job performance
	Plant-specific instrumentation, and control systems, and maintenance procedures	- Demonstrated knowledge and skills in the subjects being taught, at or above the level to be achieved by the trainees, as evidenced by previous training/education and through job performance, <u>and</u> - Completion of all qualification requirements for the senior-level instrument and control technician position at the trainee's plant or a similar plant
Chemistry Technicians	Chemistry principles; chemical analysis equipment and techniques	- Demonstrated knowledge and skills in the subjects being taught, at or above the level to be achieved by the trainees, as evidenced by previous training/education
	Plant-specific chemistry control systems and procedures	- Demonstrated knowledge and skills in the subjects being taught, at or above the level to be achieved by the trainees, as evidenced by previous training/education and through job performance, <u>and</u> - Completion of all qualification requirements for the senior-level chemistry technician position at the trainees' plant or a similar plant
Radiation Protection Technicians	Principles of radiation protection and control; radiation detection instruments	- Demonstrated knowledge and skills in the subjects being taught, at or above the level to be achieved by the trainees, as evidenced by previous training/education

TABLE 4.5.-1. (continued)

IF THE TRAINEES ARE:	AND THE SUBJECTS BEING TAUGHT ARE:	THEN THE INSTRUCTOR'S TECHNICAL QUALIFICATIONS SHOULD BE:
Radiation Protection Technicians	Plant-specific radiation protection instruments, systems, and procedures	- Demonstrated knowledge and skills in the subjects being taught, at or above the level to be achieved by the trainees, as evidenced by previous training/education and through job performance, <u>and</u> - Completion of all qualification requirements for the senior-level radiation protection technician position at the trainees' plant or a similar plant
Electrical Maintenance Personnel	Electrical principles, equipment, and maintenance practices	- Demonstrated knowledge and skills in the subjects being taught, at or above the level to be achieved by the trainees, as evidenced by previous training/education
	Plant-specific electrical systems and maintenance procedures	- Demonstrated knowledge and skills in the subjects being taught, at or above the level to be achieved by the trainees, as evidenced by previous training/education and through job performance, <u>and</u> - Completion of all qualification requirements for the senior-level electrician position at the trainee's plant or a similar plant
Mechanical Maintenance Personnel	Mechanical principles, equipment, and maintenance practices	- Demonstrated knowledge and skills in the subjects being taught, at or above the level to be achieved by the trainees, as evidenced by previous training/education
	Plant-specific mechanical equipment and maintenance procedures	- Demonstrated knowledge and skills in the subjects being taught, at or above the level to be achieved by the trainees, as evidenced by previous training/education and through job performance, <u>and</u> - Completion of all qualification requirements for the senior-level mechanic position at the trainees' plant or a similar plant
Instructors	Fundamental or advanced instructional skills training	- Demonstrated knowledge and skills in the subjects being taught, at or above the level to be achieved by the trainees, as evidenced by previous training/education

To qualify for more advanced assignments, the instructor has to demonstrate competence in carrying out classroom training and has to complete additional training. These assignments may include the following:

- Instructional development.
- Planning and developing instructional lessons.
- Developing lesson plans.
- Selecting, developing, and modifying instructional materials and media.
- Developing instructional measurement methods.
- Presenting laboratory instruction.
- Managing individualized instruction.
- Conducting walk-throughs and station tours.
- Conducting simulator training.
- Supervising on-the-job training.
- Trainee stress identification.

A learning objective for advanced instructional training might be as follows:

Example: Learning objective - advanced instructor training.
Given training-related information, the instructor trainee should be able to prepare a lesson plan that contains at least the following elements:

- plant system and task (or duty task)
- terminal learning objectives
- instructional material and media
- presentation of content narrative
- trainee assessment
- physical arrangements
- estimated time

A description of the Swedish approach to instructor training is given in Appendix L. Appendix M gives examples of the criteria used in the assessment of a lesson delivered by an instructor.

4.5.2.3. Certification

The training manager, in conjunction with other appropriate individuals, should certify that the instructor is technically qualified to present the material and has the instructional skills to perform the instructional tasks as needed for a specific job position.

Certification of technical competence should be based on a demonstration of the appropriate level of technical expertise in the subject area to be taught by the instructor. Certification of instructional capability should be based on demonstrated performance of the instructional tasks for the specific instructor position. The final certification of an instructor is achieved by sitting in on a number of his training sessions and evaluating his performance. This approach, by a senior instructor, will have been used to assist the instructor in the development of his instructional skills and ultimately as the basis for his certification.

4.5.2.4. Continuing Instructional Training Programmes

Continuing training programmes should be established to maintain, improve and advance both the technical competence and the instructional skills of qualified instructors. The continuing instructional training programme consists of:

- Continuing technical training. The purpose of this training is to maintain technical qualification and familiarity with job requirements, plant changes, operating experiences, plant documents, etc. Instructors should maintain their job qualification by fully participating in continuing training programmes in the area of expertise for which they are providing instruction. All instructors should periodically work in the plant in the discipline for which they are qualified and for which they prepare trainees. In the case of simulator instructors this should include time on shift which should be scheduled to include the shutdown and startup associated with refuelling outages. Many operating organizations periodically rotate technical instructors back to the plant and/or assign plant personnel to the training staff for extended periods.

- Continuing instructional skills training. This training is intended to improve and advance the instructors' instructional skills. The training consists of reviewing selected initial training topics, in-depth instruction on selected topics, information of new instructional methods and media, information on changes in training- related regulations or procedures, and observing and evaluating other instructors. This training should also include content based on feedback from assessments of instructors and evaluation of training programmes.

4.5.3. Pre-Testing Trainees

The entry-level knowledge and skills of the trainees must meet the prerequisites established for the training programme in order for trainees to accomplish the learning objectives. When the backgrounds and competence of trainees are not accurately known in advance, a pre-test should be adminstered before starting the training. The information obtained from such pre-tests is important to direct the instructor to the best strategy to be used in order to achieve the learning objectives.

Specifically, the pre-test results can be used for:

- Confirming individual trainee qualification to enter into the training programme.

- Identifying necessary additional (i.e., remedial) learning needs for the trainees who did not satisfy the entry criteria.

- Identifying parts of the training programme for which an accelerated schedule could be applied owing to confirmed trainee mastery of the subject material.

- Defining a learning strategy on the basis of weaknesses and strengths of a particular group of trainees.

4.5.4. Instructor Preparation For Training

Prior to conducting each lesson of the training course, the instructor must prepare himself to deliver that lesson. During preparation, the instructor should review the total content of the lesson (in accordance with the lesson plan) and identify the parts which need more attention or need special explanation. In this phase, the instructor must review the status of training facilities and materials (procedures, drawings, textbooks, tools, media, models, simulator, classroom facilities and equipment) needed in training. Any requisite correction or repairs to training materials or facilities should be effected prior to the start of the training session.

In the case of a simulator training session, the instructor must check that the state of the simulator will be satisfactory for conducting the training, e.g., no defects are present which would inhibit the satisfactory achievement of the learning objectives. If in doubt or if the exercise is new to him, he should arrange to go through the lesson plan using the simulator. He should also satisfy himself that up-to-date copies of all documentation available in the power plant control room are available in the simulator facility for use by the trainees.

In addition to reviewing the lesson plan, all instructors should review the procedures for monitoring progress and trainee tests relevant to that particular portion of training.

4.5.5. Implementation of Classroom Training

The content of the lesson is outlined in the lesson plan, an example of which is given in Appendix J.3. The lesson plan also defines instructor and trainee activities and the main resources to support training.

To deliver a good lesson, the instructor must be fully familiar with the subject of the lesson, and with the relation of the subject to practical use and to the terminal learning objectives. The lesson has to be delivered clearly and in a concise manner. Practical examples are very useful, but only if they are strictly related to the subject of the lesson.

It is very important that the presented materials correspond exactly to what must be learned. A confused redundant lesson would distract the trainees and demotivate them from following the lesson with the necessary attention.

It is equally important to find methods for securing trainee interest and attention to the lessons. Some useful approaches are:

- Involve trainees in the learning process by encouraging discussion.

- Ask questions of the trainees when some important facts are introduced in the lesson (to maintain trainee interest and to confirm that they understand the material that has been presented).

- Connect important subjects of the lesson with actual plant experience.

- Speak slowly and clearly.

- Do not make the lessons too long.

- Remove the sources of external noises and visual distractions during the lesson.

- Avoid overloading the trainees with duties, because this will create anxiety and distract them from the training.

- Use rewards to recognize achievements (appraisals, certificates, etc) and interject competition between individuals and between groups of trainees.

Training material covering exactly the subject of the lesson should be available to the trainees in a timely manner.

Effective classroom training depends on the availability of sufficient time between lessons to allow the trainees to review the content of past lessons, to consolidate the knowledge, and to prepare for the following lesson. In implementing a training programme, a balance should be sought between lesson periods and periods reserved for trainee self-study. In addition, classroom training should be alternated with practical (e.g., on-the-job or simulator) training or plant walk-throughs.

It is also a good practice at the end of each lesson for the instructor to summarize the main ideas developed in that lesson and to indicate to the trainees what is essential to be understood and learned and how this relates to the learning objectives. A short quiz at the end of a lesson can help reinforce the main points and the learning objectives.

Classroom training can often be enhanced by the use of appropriate media such as audio and video devices and models of plant components.

4.5.6. Implementation of On-the-Job Training

An example of an on-the-job training guide used for the implementation of on-the-job training is given in Appendix J.4.

The persons who implement on-the-job training should be individuals currently qualified and working in the positions for which the trainees are being trained. In addition, they should receive instruction on the proper methods of conducting such training and should understand their role in the training process. This includes understanding the:

- Overall concept of on-the-job training.
- Methods of developing required trainee knowledge and skills.
- Methods of performing trainee progress checkouts.
- Application of established standards in the trainee assessment process.
- Action to be taken in cases when the trainees do not satisfy the assessment criteria.

When assigning trainers to on-the-job training, attention should be paid also to their personal qualities, such as communication skill, judgment ability, personal maturity, and general attitude to training and to assigned tasks.

A selected individual (usually from the training department) should be in charge of coordinating on-the-job training. Some of the main coordination duties are to:

- Follow the training schedule and assign milestones in the training process.

- Monitor the trainees' progress.

- Provide training materials.

- Coordinate training assignments to take advantage of opportunities to train on infrequent work activities.

- Document the training process.

- Evaluate training effectiveness.

- Secure documentation on completion of the training.

The on-the-job training guide (lesson plan) should include applicable learning objectives and should contain a section designating individuals to conduct training and to assess trainees in areas covered by the guide (see example in Appendix J.2).

The general steps involved in the conduct of on-the-job training should also be described in the training guide and should be understood by the trainees, trainer and assessor.

On-the-job training can be divided in three main phases:

- Instruction phase
- Training phase
- Assessment phase

In the first phase, the trainee is prepared for on-the-job training by being familiarized with all relevant references, such as the following:

- Instruction in the use of the materials.
- Target dates to complete particular parts of the training.
- On-the-job training checklists, objectives and references.
- Supporting study materials (drawings, flow diagrams, procedures, system descriptions, etc)

The referenced materials should contain all necessary data on systems or components included in the training (descriptions, functions, precautions, safety limits, alarms, controls, trips, interlocks, normal and abnormal operating modes, etc). Besides studying the training material, the trainee discusses important items with the trainer.

Next, the trainer demonstrates the functions of systems or components (if permissible by the plant status), explains the consequences of improper performance, explains the current industry practices relative to the particular item, and answers trainee questions. If the plant status prevents demonstrations, then the trainer will simulate the operations on the plant.

The practical work of the trainee follows these demonstrations. This work, depending on the nature of the on-the-job training, consists in: demonstrating a particular skill (for example, the startup of a circulating water pump or the dismantling and repairing of a component or instrument); a walk-through of the activity with a qualified trainer; or performing an equipment operation function.

The trainer corrects observed performance deficiencies and helps the trainee to improve his skills.

When the trainee and trainer are confident that the trainee has mastered a specific item of the training programme and that the trainee should be able to meet the relevant training objectives, a check of the performance is requested from the designated assessor.

On-the-job training concludes with this assessment phase. The person designated for the assessment is an experienced person not involved in the conduct of on-the-job training.

The trainee assessment phase can be described by the following sequence:

- The training assessor schedules the checkout.

- The assessor conducts a checkout of acquired trainee skills and knowledge achieved in training using the pre-established evaluation standards and learning objectives.

- If the assessor finds the skill and knowledge of the trainee satisfactory, he signs off the assessed item. If not, he directs the trainee to upgrade his skill and knowledge by further training.

- The assessor provides feedback to the training department on any necessary improvements in on-the-job training on the basis of detected deficiencies during trainee assessment.

4.5.7. Implementation of Laboratory/Workshop Training

Many aspects relating to the conduct of both classroom and OJT are applicable to laboratory/workshop training. In many situations, this setting is a more favourable environment for learning a skill, e.g., fault-finding in an electrical circuit, than the on-the-job setting. As with all training activities, the conduct will be in accordance with an approved lesson plan to achieve the learning objectives and be undertaken by a competent experienced instructor. The safety of the trainees must be maintained throughout the session, and this can best be achieved by ensuring that adequate prerequisite safety training has been built into the overall training programme and that the ratio of trainees to instructors (and any technical assistants) allows close supervision to be effected.

The size of groups of trainees in the laboratory/workshop should be such that every trainee has the opportunity for hands-on practice. While this can be maximised if trainees work as individuals, small groups are usually beneficial to the learning process through the trainees' sharing of progress and knowledge in a cooperative manner. In addition, the cost of equipment or mock-ups may necessitate group work.

The introduction to a session will play just as important a role in a laboratory or workshop as for the one held in a classroom. Trainees' attitudes in all cases will be greatly influenced by the conduct of the first few minutes of the lesson. As with all training, it is imperative that the trainees understand the objectives and duration of the session, how it will be structured, the opportunities available for him to practice and the method and standards of assessment.

The lesson plan should include in its introduction a review of prerequisite knowledge and skills prior to presenting the material for the session. This section of the training will often take place in a classroom setting which may be part of the laboratory or workshop equipped with suitable instructional equipment. Handouts to trainees will include all written material they need (or references to where it can be found) together with a list of tools and/or equipment they will utilise. At some point the instructor will demonstrate the task or important facets of it, building on knowledge and skills previously acquired.

During hands-on practice by the trainees, the instructor must be alert to all the trainees and move steadily and constantly around all individuals or groups. He should make use of oral questioning to ensure important aspects are adequately understood by them. On occasion, this feedback will cause him to stop the exercise and to disseminate information to all trainees. Throughout the session the instructor should help, encourage and if necessary demonstrate the technique again.

Unlike OJT, the assessment of performance will often be conducted within the session and not as a separate session using an independent assessor. Thus, it should always be clear in advance whether the instructor's observing and questioning is part of the formal assessment process or is part of the instructional technique intended to help the trainee achieve the lesson objectives.

In concluding a lesson with the full class the instructor should involve any or all of the following elements:

- An overview of the entire task to tie together the separate items learned in the lesson.

- Questions raised by trainees.

- Discussion of problems that arose in conducting the practical exercise and ways in which they could be handled.

- References and suggestions for further study and practice.

- An evaluation of class progress.

- Discussion of how the work relates to the next lesson.

An example of a laboratory lesson plan is given in Appendix J.4.

4.5.8. Implementation of Self-Study Training

Although self-study modules are designed for self-paced learning, trainees still require support in their learning from instructional staff, supervisors and/or colleagues.

As with all training programmes, the trainee should have a clear statement of the objectives and well-defined learning tasks. The support person's role is normally to monitor trainees' progress through the module, to check that they are up to date with their work, to detect problems or difficulties at an early stage and to deal with them. A variety of self-study situations exist, each requiring its own particular support and monitoring arrangements to be specified, for example:

- Self-study of training materials to reinforce instruction received in a classroom or similar setting.

- Self-study of training materials in a training setting or centre.

- Self-study at home.

- Self-study in the work place, e.g., plant systems training.

In addition to assisting with difficulties and problems, the designated support person should be in a position to assist in the location of suitable supplementary resources.

The method of assessment will depend on the training media utilised. In the case of computer-based training, the software will normally incorporate intermediate as well as final assessments, and thus the requirement will be to interrogate it. For other media, the traditional oral and written methods of assessment are relevant, plus plant walk-throughs if the self-study has been associated with, for example, establishing knowledge of power plant systems and their location. In the case of oral assessment and plant walk-throughs, the assessor should be independent of those providing support during the self-study training period. As with all training, it is important that adequate records of the competencies achieved by the trainees be established and maintained.

4.5.9. Implementation of Simulator Training

Simulator training sessions using the appropriate lesson plan or exercise guide (see Appendix J.1) should be implemented in three parts:

- Pre-exercise briefing.
- Simulator exercise.
- Post-exercise debriefing.

Simulator team training should always be conducted with the same number of people as would normally compromise a shift team in the control room of the nuclear power plant. This approach contrasts with the individual skill development which takes place during initial training and which requires the trainee to develop his team skills only after the development of individaul skills is mastered. In developing his individual skills, simulation devices of less than full scope are appropriate for providing training and demonstrating that performance standards have been achieved before progressing to a replica full-scope simulator. In developing team skills towards the end of an initial training programme, the balance of the control room positions can be filled by experienced plant staff or by instructors. Additional trainees can observe the simulator exercise and take part in the briefing and debriefing sessions, rotating with other trainees to gain hands-on experience.

4.5.9.1. Pre-Exercise Briefing

Simulator training is more effective when the trainee is introduced to the learning objectives and given a review of prerequisite knowledge and an understanding of any principles or procedures that will be used prior to running the exercise. The exception to this approach occurs when the purpose of the exercise is to provide practice responding to unannounced malfunctions or to assess trainees' performance. The trainees should be assigned to team positions and given a full understanding of what actions are expected of them. When the exercise is part of the continuing training programme, the shift team will take up their normal control room positions.

Any expected simulator response that differs from what would be expected at the plant should be brought to the trainees' attention. This is essential, if the training is taking place on a simulator which does not fully replicate the trainees' man-machine interface or plant system.

During the briefing session, all relevant plant information should be made available to the trainees including such items as:

- Previous power history
- Plant conditions
- Evolutions in progress
- Planned evolutions for the "shift"
- Equipment out of service
- Abnormal equipment line-ups.

Briefing sessions can take place in a classroom or in an area adjacent to the simulator equipped with appropriate instructional aids.

4.5.9.2. Simulator Exercise

It is important to reinforce realism during the exercise and thereby to assist the trainees to develop good operating practices. Thus, the instructor must stress areas such as control room formality, use of procedures, shift team roles, communications, log keeping and emergency plan implementation.

The conduct of simulator training will vary depending on the type of training being undertaken, e.g., initial reactor operator training, continuing training, upgrade training, training for managers, maintenance and other non-control-room staff. Consequently, care should be taken to design and conduct the training to meet the training needs of the individuals and the team.

Videotaping may be used during simulator exercises to record trainee actions. Such tapes can be used by the instructor to augment post-exercise debriefings, or the videotapes may be reviewed by the trainees in a self-evaluation session under the guidance of an instructor. Videotapes can also be used to demonstrate good performance in control room activities.

During the initial stages of training, instructor interaction with trainees should be high, to demonstrate proper performance and to correct improper performance. Simulator functions such as freeze and backtrack should be used to point out parameter trends, to demonstrate operating principles and to identify and correct errors as they are made.

During the later stages of initial training and during continuing training, the amount of instructor involvement should decrease to allow the student to learn from mistakes.

Simulator exercises should be allowed to progress to the point where either the training objective is achieved or the trainees are unable to diagnose and respond effectively to the event. In the latter case, the simulation should be stopped, immediate feedback provided and the exercise resumed when the instructor is satisfied that the situation has been adequately clarified.

Trainees' basic knowledge and skills should be developed before off-normal exercises are introduced. Some utilities structure simulator training as three modules progressing through normal, abnormal and emergency training exercises. Within this hierarchy, operations can also be classified as stressful, complex, sensitive or rare. As discussed in Appendix F, scenarios falling into these categories should be included in the simulator training programme. Many utilities find it beneficial for trainee control room staff to spend the time between modules in the power plant. These periods are spent on-shift reinforcing lessons learned on the simulator and preparing for the next training module. This is carried out under supervision by studying appropriate plant documentation and especially technical specifications, safety reports and relevant operating procedures. In some utilities, these activities are the subject of formal classroom training sessions.

The development of training simulators has been such that generic malfunctions on individual plant components are now available to the instructor. Not only can he "fail" hardware components such as pumps and valves but also he can interface with instrumentation and control signals. While this provides a virtually infinite number of malfunctions at his disposal, care should be taken to avoid deviation from the lesson plan during the course of the simulator exercise. Not only could unscheduled malfunctions move the simulation into a previously unvalidated situation, but consequent trainee and instructor activities will not have been determined.

It is not possible to use current simulators for accident scenarios which progress significantly beyond the design basis accident, e.g., into core degradation. This is due to limitations with respect to the availability of validated data and equations. It is possible for the instructor to stage simulator scenarios that will progress beyond the design basis. Before the simulation goes beyond its validated boundaries, it should be terminated and the exercise continued through instructor-led discussion. In this situation he can make use of design-code-based information to review possible long-term actions by the crew, which will enhance their knowledge base. In the event of such an accident, it can be envisaged that instructions with respect to plant manipulations will come from the emergency management group external to the control room (see Section 2.6); hence training need/may only be to develop the knowledge base and to practise a range of plant manipulations, e.g., shutdown from the auxiliary shutdown room (subject to the appropriate handicaps, such as the wearing of breathing apparatus).

It is essential that the control room team be well trained on how and when to use procedures. Procedures may have limitations and thus should not be followed blindly. Rather, procedure use should be coupled with an ongoing, logical thought process; thus, there must be an emphasis on teamwork and diagnostics training in both the initial and continuing training programmes. The aim should be to provide operators with practice in applying the fundamentals of effective communication, teamwork and problem-solving taught in the classroom. This will entail the implementation of simulator exercises designed to improve proficiency in the topics, which will be enhanced by:

- Maintaining a professional approach and attitude to the position responsibilities
- Detecting problems early by trending key parameters
- Anticipating problems during error-sensitive plant manoeuvres
- Paying attention to the details of plant parameters and conditions, to prevent incidents
- Using procedures.

The number of instructors involved in conducting a simulator exercise should be sufficient to accomplish the simulator operation, instruction, role-playing and trainee assessment activities defined in the lesson plan. Some simulator training activities, especially trainee assessment, require the involvement of two instructors.

Trainee Assessment on the Simulator

Effective training requires that individual and team performances be assessed during and at the completion of the simulator training programme. During the programme, the information is valuable for measuring trainee accomplishment of objectives and providing guidance on areas of weakness which can be addressed during subsequent training sessions.

The assessment of staff during a simulator exercise should be conducted in as objective a way as possible. Schemes have been developed which utilise a range of criteria for each of the following assessment parameters:

- Awareness
- Event diagnosis
- Immediate/entry level actions following malfunction injection
- Subsequent actions

- Desk and panel manipulations
- Use of procedures/technical specifications/reference data
- Communications
- Supervisory ability.

The instructor undertaking the assessment utilises the criteria listed against each parameter - which are grouped as: appropriate to unsatisfactory, satisfactory and excellent performance. Through regular logging throughout a simulator exercise, it is possible to build up information which enables the trainee's performance to be determined. On some simulators, computerized logging/recording of operator actions and major parameters can be used to assist the instructor.

Examples of simulator exercise assessment guides for individuals and teams are given in Appendix N, which includes a method being developed in Hungary for the computer-based recording of trainee performance during a simulator exercise.

During assessments, the instructor should try to limit his/her activities to observing the actions of the trainees to determine if they meet performance standards and to take appropriate notes, record times, and procedures used and include questions for follow-up.

4.5.9.3. Post-Exercise Debriefing

A debriefing should be conducted at the conclusion of each exercise to reinforce appropriate responses and to correct weaknesses. This may involve rerunning portions of the exercise or using the monitored parameters function of the simulator to show what happened during the exercise. Observations made during simulator assessments may be supplemented during the debriefing by questioning the trainee to determine his knowledge level. Videotape recordings can make a useful contribution, particularly when reviewing teamwork. It has been found to be very beneficial for the operators to criticize their own performance and the performance of others during the exercise.

It is beneficial, when reviewing emergency training scenarios, for the instructor to promote a review and discussion which extends beyond the potential emergency into a degraded core scenario, to highlight:

- Essential operator actions and safety system responses to prevent meltdown

- Ameliorating actions to recover the situation at intermediate points

- Accident management strategies and emergency plan arrangements.

4.5.9.4. Use of Non-Plant-Specific Simulators

The ideal simulator training setting for initial and continuing training of control room personnel is one which is plant-specific and full-scope with a replica of the control room desk and panels. While not ideal, other types of simulator sometimes have to be used (e.g., before delivery of a simulator for a plant about to start up). Provided the relevant functions for availability and safety are adequately represented on the chosen simulator, training can be undertaken by attention to the following points:

- The station procedures should be modified for use on the training simulator.

- Instructors should be fully trained to understand the differences between the plant and the simulator.

- The training programme should begin with a classroom lesson describing the differences and a simulator session during which the trainees familiarise themselves with the simulator desk and panel layout.

- Reinforcement of the differences, concentrating on the plant behaviour, should occur during each post-exercise debriefing.

4.5.9.5. Full-Scope Simulator Training for Non-Control-Room Personnel

Simulator training for groups other than control room personnel has been found to be beneficial. The aim is to provide them with simulator training to develop a technical understanding of the integrated operations of the plant or details of the operation of a specific system, instrument control loop or component. Staff who may benefit from this type of training include:

- Managers
- Engineers and Technical Staff
- Shift Technical Advisors
- Instrument and Control Technicians
- Field Operators (Roundsmen)

As these staff do not perform hands-on operation of the plant from the central control room, simulator training is conducted with the instructor demonstrating plant operating fundamentals and principles. It is neither necessary nor cost-effective for such trainees to learn the desk and panel layout such that they can undergo hands-on training. However, they can beneficially be allowed to operate controls under the instructor's supervision as a means of enhancing their learning. Owing to the method of training, the numbers who can participate can be higher than for control room operator training.

4.5.10. Assessment of Trainee Performance

Assessment of trainee performance during and at the completion of training is an essential activity in conducting training. These assessments are necessary to determine whether trainees are achieving the learning objectives and to verify that they achieve the competence required to perform the job for which they have been trained. The assessments also give feedback information to training instructors and plant management on the effectiveness of the training programme and data on the success in the selection of trainees for that particular training. The feedback information from the assessment should be used to make improvements in the training programme as necessary (see Section 4.6.).

Trainee performance must be assessed regularly during each course and at the completion of the training programme, as scheduled in the training plan and the lesson plans. The schedule for the tests should be known in advance by the trainees.

The test items and tests to be used for trainee assessment are developed during the training programme's design phase, as described in Section 4.3. Assessments used to verify competence upon completion of training as much as possible should be related directly to actual job tasks performed in the job environment (with normally available tools, procedures, etc).

Test results should be provided to the trainees as soon as possible after the test. The test results should then be reviewed jointly by the instructor and the trainees. Deficiencies should be identified and advice given to the trainees on necessary improvements.

Trainee performance and progress during training should be monitored closely and continuously. The data for this progress monitoring should derive not only from tests but also from daily discussions, resolving questions during lectures, performing practical work, etc. Trainee mastery achieved in training must be related to the learning objectives of particular training modules.

Standards for assessing trainee performance should be applied consistently. Trainees not meeting the pre-established standards should not be allowed to progress to the next stage of the training until deficiencies have been corrected.

Trainees who show weaknesses in tests or generally show insufficient progress in training should be interviewed by the instructor to identify the reasons for their difficulties. Then such trainees should be advised on how to improve their performance (by using extra lessons, retaking parts of the training, self-study, help from other trainees, etc). Any remedial actions to correct the observed deficiencies should be agreed to by the trainee's job supervisor. In cases when the remedial actions do not contribute to improved performance, the trainee may be removed from further training.

The methods for competence verification defined in lesson plans and training guides may be oral or written examinations or performance demonstrations.

It is good practice for the competence verification to be integrated with the conduct of training. By such an approach, the instructor gradually, prior to final examinations, acquires confidence in the competence of the trainees. The final examination is used only as a confirmation of the already expected level of trainee skills and knowledge.

Through such an approach, the possibility of misjudgement is to a large extent avoided, and the negative effects of trainee stress concerning examination results are minimized.

In addition to operating organization assessment of trainees, it is a requirement in some countries that trainees for certain positions successfully complete an examination conducted by the external regulatory body. An example of the syllabus and form of examination undertaken by trainee reactor operators in Czechoslovakia is given in Appendix P.

4.5.10.1. Assessment Techniques

Assessments are given to test a person's knowledge of a specific topic or his ability to perform a task. There are several types of performance evaluation techniques utilized during training programmes: written and oral examinations, and practical performance demonstrations (workshop, simulator, on-the-job qualification). Each of these has a specific purpose and role in the assessment process.

<u>Written Examinations</u>

Written examinations are a very important part of the assessment process and are particularly applicable to classroom and self-study training. Written examinations are a convenient mechanism for measuring how effective the lessons have been. They are held as progress tests during the conduct of the training and as final examinations.

It is self-evident that the proposed content of examinations must be held strictly confidential.

The main advantages and disadvantages of written examinations are:

- Written examinations have the advantage of enabling the instructor to examine a large group of trainees simultaneously and of allowing sufficient time (several hours) for trainees to work out numerical examples, to draw diagrams and sketches, to describe answers, etc. Additionally, written examinations provide documentation of trainee performance.

- They have the disadvantage of not allowing the individual to express fully his knowledge and mastery of a subject, and also many individuals (especially those with lower educational levels) have difficulty in expressing their knowledge in a written form clearly and in a logical sequence.

Written examinations can make use of three types of question:

- Multiple choice questions
- Short answer
- Essay

Multiple choice quesitons are easy to administer and enable a large number of knowledge items to be tested in a short period of time. They are particularly useful for the recall and comprehension levels of intellectual ability (see Section 4.2.2.), but need care in their formulation.

Short-answer questions require the trainee to provide a phrase, sentence or diagram as a response. They have the benefit that, unlike multiple choice questions, no stimulus by way of possible answers is provided.

Essay questions provide the most satisfactory written means of assessing a trainee's competence at the high levels of intellectual ability - application and evaluation. While essay questions based on learning objectives included in the training programme are relatively easy to develop, their judging and grading takes longer and is more difficult than with the other two types of questions.

Oral Examinations

Oral examinations are another method of assessing trainees. As with written examinations, oral examinations must be carefully prepared and reviewed to ensure that they accurately assess trainee competence in relevant topics and accomplishment of learning objectives. This includes preparing the questions in advance and ensuring that each question is job-related.

Indicating the key items expected in answers will help in maintaining objectivity and provide for immediate feedback to the trainee when the correct answer is not obtained.

When a response requires the use of training material, plant documents, drawings, media and/or some component, care must be taken to ensure that these are made available to the trainee in due time, or that he knows that he is responsible for obtaining that material in order to answer the question.

Oral examinations should be well documented. Examination forms should be prepared for each trainee which contain question areas, a summary of assessment answers, and the assessor's remarks. The examination forms should be filed as examination records for future use.

The advantages and disadvantages of oral examinations are the following:

- Oral examinations give almost unlimited possibility to the trainee to express in his own words his understanding of the topic.

- This type of examination gives the assessor a better insight into the trainee's overall knowledge and allows him to investigate more deeply the trainee's understanding of the subject through additional questions.

- Oral examiantions can provide immediate feedback to trainees when a wrong response is obtained.

- The disadvantage of oral examinations is in requiring individual assessment of each trainee, and thus not allowing sufficient time to work out calculations, demonstrate knowledge in practical usage of mathematical expressions, in developing systems diagrams, etc. Also, the quality and effectiveness of an oral examination depends on the examiner's skill. Therefore, it is recommended that several qualified examiners participate in final certification oral examinations.

- There is a risk of personal bias, of inadequate sampling of the trainees' knowledge, and of the interference of many factors not related to the training criterion.

The best practice is to combine written and oral examinations. This choice takes advantage of the benefits of both examination techniques.

<u>Performance Demonstrations</u>

Performance demonstrations are used to measure the skills and knowledge acquired by the trainees in on-the-job, simulator, workshop or laboratory training. Performance demonstrations are similar to oral examinations but generally require the trainee to demonstrate proficiency in a specific task using appropriate procedures, tools, equipment or a simulator, as necessary.

Performance proficiency is an important aspect of training in the areas of maintenance (mechanical, electrical and I&C), chemistry, radiological protection and operation.

The assessment should be based on learning objectives and task performance standards for each area. Specific aspects associated with the assessment of trainees in on-the-job, laboratory/workshop and simulator training are discussed in Sections 4.5.6., 4.5.7. and 4.5.9., respectively.

Satisfactory completion of the performance demonstration must, as in the case of oral examinations, be properly documented. On the completion of the demonstration, the document should be properly filed and preserved for future reference.

4.5.10.2. Feedback

The trainees should be provided with prompt, regular and objective feedback on their performance from any assessment method. The test results from written tests should be scored and returned to the trainees, preferably within a day, but in no more than a week. The test results should then be discussed in a critique session to point out weaknesses and to indicate areas of necessary improvements.

Identification of trainee weaknesses is relatively straightforward. Finding the causes of those weaknesses is not as simple, and more training is not always the solution. One method of identifying weaknesses is in careful evaluation of aggregate results of oral, written, and performance tests to identify potential areas of weaknesses, both in the training and in the testing methods. If some of the test items are frequently answered incorrectly, this may indicate a weakness in the training programme, not the trainees.

In addition to feedback provided for overall performance assessment, feedback should also be provided on specific skills and knowledge that do not meet job performance requirements.

4.5.10.3. Performance Below Required Standards

Trainees who perform below required performance standards should be provided with remedial training and retested. The trainee should be removed from the training programme if, after remedial training, the required standards are still not met. The procedures to be applied when the trainee cannot meet the performance standards should be defined in appropriate written procedures.

The trainee should not be allowed to proceed to a higher training level before his performance at the lower level is found satisfactory. Since the training is normally held for a group of trainees, the time available for individual remedial training is rather limited.

When the root causes of the difficulties is found to be in the initial training programme, special training techniques should be used to correct them. This would require careful analysis of the original training programme, including inputs from the trainees. Information regarding trainee deficiencies should also be used as feedback into the programme. (See Section 4.6.)

Similarly, job incumbents performing below required standards during requalification or continuing training should be removed from the associated job duties and provided with remedial training. Continued failure to achieve the required performance standards will necessitate removal from the training programme and the job.

4.5.11. Training Records

The establishment of training records is an essential part of a properly implemented training programme. Two types of records are required:

- Training programme as implemented.
- Trainee performance as assessed.

Records of the training programme as implemented will include details of the actual schedule, training facilities utilised, trainee handouts, lesson plans, and examination questions.

For each trainee, data on his/her progress should be recorded. This will include test and examination data and instructors' assessments of trainee attitudes and competence.

In reviewing a training programme to identify possible improvements, it is desirable to put together the above information, including instructor and trainee feedback determined through the evaluation process described in Sections 4.6.2.7. and 4.6.2.8. This collation should be done by the instructor responsible for conducting the programme and be reviewed by his supervisor.

4.5.12. Summary

- The implementation of training can be split into four activities:
  - Preparing the instructors.
  - Pretesting the trainees.
  - Delivering the lesson (or conducting the on-the-job, laboratory/workshop, simulator and self-study training).
  - Assessing the trainee performance.

- Developing competent instructors requires appropriate subject matter expertise and instructional skills competence.

- More advanced instructional training is required for duties associated with training settings outside the classroom and for activities associated with training design and development.

- All instructors should be assessed against performance standards for their competence to undertake defined tasks; this process is commonly referred to as certification.

- Continuing training is required for instructors and should cover both technical knowledge and instructional skills.

- Pretesting of trainees is important to establish that they have the prerequisite skills and knowledge necessary to undertake the training programme.

- Instructors must be fully knowledgeable about the lesson plans, facilities and equipment they will utilise in delivering a lesson.

- Classroom instruction is the most widely adopted training setting. Its effectiveness is enhanced by the use of training media such as transparancies, audio and video devices and scale plant models.

- On-the-job training is usually conducted by job incumbents who have been trained to deliver this form of training. Progress is monitored through the training organisation, and assessment is carried out by an independent assessor.

- Laboratory/workshop training requires adequate supervision to ensure safe working practices. Trainee group sizes should take into account the need to practice the skills taught and demonstrated by the instructor and will also be determined by the availability of the necessary equipment and tools.

- Self-study training can be undertaken in a variety of settings such as home and at the work place. In all cases the trainees require support from a designated expert.

- Simulator training exercises should be undertaken in three parts:

  . Pre-exercise briefing
  . Simulator exercise
  . Post-exercise debriefing

- The use of non-plant-specific simulators requires careful preparation and thorough explanation of the differences between plant and simulator.

- Exercises should be conducted until either the training objective has been achieved or the trainees are unable to diagnose and respond effectively to the event.

- Instructors should help trainees to develop good operating practices, use procedures, improve diagnostic techniques, communicate effectively and work well as part of the shift team.

- Assessment of training in all settings to defined performance standards provides feedback to the trainees, instructors, training management and plant management. Techniques which are available include:

  . Written examinations
  . Oral questioning
  . Performance demonstrations

- Each technique has advantages and disadvantages; a combination of written and oral techniques has been found to be the most appropriate for knowledge and performance demonstrations, supplemented by oral questions for skills testing.

- Assessment of simulator training should utilise prepared checklists to improve objectivity.

- Following all assessments both during and at the end of a training programme, feedback should be provided to trainees.

- Records of all training conducted, and details and results of all assessments should be established and maintained.

- Failure to achieve specified performance standards will necessitate either remedial training or removal from the training programme.

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4.6. MAINTAINING AND IMPROVING TRAINING PROGRAMME EFFECTIVENESS

4.6.1. Introduction

Training programme evaluation and upgrading is essential to achieve well-organised and effective performance-based training and to ensure that employee competence is developed and maintained. The goal of programme evaluation is to determine the effectiveness and efficiency of the implemented training programme and to provide input for its revision if necessary. The key aspect of training programme improvement is to learn from experience.

Internal training evaluation should be an integral component of nuclear utility training. Utility management should be directly involved in the evaluation of training programme effectiveness, because effective training will contribute to plant safety and reliability.

Training programme evaluation includes evaluation of trainee test results, trainee and instructor critiques, feedback from supervisors, feedback from trainees after they begin work in their new positions, formal programme evaluation, and evaluation of training staff performance. However, the primary indicators of programme effectiveness are plant performance, plant operations experience, and personnel performance. The evaluation process also collects information on new or changing training needs (e.g., plant modifications and procedure changes) and initiates appropriate training programme changes.

Evaluation of programme effectiveness focuses on the achievement of learning objectives and not on the training process. The evaluation process identifies performance problems that can be solved by improved training.

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* Papers presented at the Seventh Symposium on Training of Nuclear Facility Personnel, Orlando, Florida 1987.

** Paper presented at the CSNI Specialist Meeting on Training of Nuclear Reactor Personnel, Orlando, Florida, 1987.

The main evaluation activities are:

- Collecting information on training programme effectiveness and on new or changing training needs
- Analysing collected information to determine needed improvements in training programmes
- Initiating actions to revise and improve training programmes.

4.6.2. Collecting Information on Training Programme Effectiveness and Changing Needs

The sources of information on training programme effectiveness and factors influencing changes in training needs are as follows:

- Feedback from plant operating experience
- Industry-wide operating experience
- Reports from plant inspections and evaluations
- Plant modifications and changes in plant procedures
- Feedback from job supervisors
- Feedback from programme graduates
- Trainee evaluation of training programmes
- Feedback from instructors
- Feedback from performance of operators on the simulator

4.6.2.1. Feedback from Plant Operating Experience

Plant operating experiences present a valuable source of information on the effectiveness of training programmes.

Because plant performance is highly dependent on power plant personnel performance, it is a good indicator of the effectiveness of the training programmes. The review of experience in handling abnormal operating conditions and plant transients, as well as data on the number of plant trips, equipment failures, unscheduled maintenance, excessive plant unavailability or unsafe practices may indicate deficiencies in some parts of the training programmes.

Review and analysis of job incumbents' performance in specific situations requiring diagnosis of events, use of procedures, timely corrective actions, and promptly locating and repairing defective components may indicate weaknesses in training (but may also indicate other weaknesses).

The analysis of plant operational experience may also indicate if job performance standards are different from those used in training.

Also, the frequency of observed operator errors is of importance for judging training programme effectiveness. If errors are consistently repeated, the conclusion may be that corresponding parts of the training programme have to be revised and improved. This may necessitate modifications to the simulator to extend the scope of the training exercises conducted on it. Both hardware and software changes could be required.

4.6.2.2. Industry-wide Operating Experience

Industry-wide operating experience, especially operating events at similar plants, is also likely to influence the content of training programmes. Incorporating industry operating experience into training enables utilities to benefit from each other's experience.

Sources of information on nuclear industry experience include reports on operating and maintenance events distributed through national and international channels (e.g., utility associations, owners groups, IAEA, reactor vendors, etc).

4.6.2.3. Reports from Plant Inspections and Evaluations

Nuclear power plant inspections to evaluate plant safety and reliability can also provide a valuable source of information on training programme effectiveness. The evaluation of plant operations performance is usually effected at various levels:

- Internal plant evaluations: Internal evaluation should be performed by the safety engineering group and by the quality assurance group. Reports should be submitted to plant management.

- Evaluation by external organisations: In some cases, utilities have created a joint organization to evaluate the operational safety and reliability of individual plant performance. The reports are for internal utility use, but recommendations are based on wider utility experience. In addition, the IAEA has established its OSART missions, which include training among the activities reviewed by OSART team members against international best practices (see Ref. [2] Section 1.7, for OSART results).

- Reports from regulatory inspections: Reports from regulatory inspections often contain a number of observations and remarks important for training activities. The correction of training programmes based on these observations is in many cases mandatory.

4.6.2.4. Plant Modifications and Changes in Plant Procedures

It is evident that effective training programmes (both initial and continuing training) must incorporate training to develop skills and knowledge related to plant modifications (design changes, system and component modifications) and changes to plant documents (procedures, technical specifications, equipment manuals). These changes should be incorporated into initial training programmes before the next class is conducted, and the training of incumbents should be completed before new procedures become effective.

A system must be established which routinely provides information on proposed plant modifications and proposed changes in plant procedures to the training organisation for action as indicated above. It is particularly important to evaluate the system in terms of its impact on the simulator. The time taken to modify simulator hardware and software can be significant; hence, an effective system for the transfer of both approved proposals and their subsequent implementation details is essential if timely training is to be provided.

4.6.2.5. Feedback from Job Supervisors

A formal approach periodically to solicit supervisor feedback on job performance problems is an integral part of training programme evaluation.

Supervisors are qualified to describe common performance problems and identify anticipated changes in job requirements. They should be consulted periodically concerning how well training is preparing new employees to perform their jobs and what additional or refresher training is needed for current employees.

The information obtained from supervisors should be used to improve both initial and continuing training. Collected information should include:

- Tasks for which recent graduates are inadequately prepared
- Types of errors committed by job incumbents
- Suggestions for improvements in initial and continuing training programmes
- Expected changes in job assignments, procedures and equipment

4.6.2.6. Feedback from Programme Graduates

A formal programme for collecting feedback information from job incumbents three to six months after they complete training should be implemented and the data used for training programme evaluation for initial and continuing training.

To accomplish a systematic survey of graduates' evaluation of training programme effectiveness, a questionnaire should be prepared asking, for example, the following questions:

- What additional training have you received since being assigned to the job?

- What unexpected difficulties or problems in job performance have you experienced?

- Has your supervisor given you instructions different from those received in training?

- Have there been other differences between the training received and what is now expected of you on the job?

- What changes have occurred in your job since you were assigned to it?

- What kinds of errors have you or other new employees committed on the job?

- How could training have better prepared you for the job?

- What suggestions would you make to improve the training you received?

- What additional training do you need for your job?

Information collected from graduates should be confirmed before actions are taken to modify training.

4.6.2.7. Trainee Evaluation of Training Programmes

Trainees, at the end of training, should be given questionnaires intended to collect their viewpoints on training programme quality. (See Appendix Q for examples). The collection of trainees' first-hand opinions on the conduct of the training can be used as valuable information for training programme improvement. The questions to be asked of the trainees should cover the following general aspects:

- Overall assessment of the course
- Adequacy of time allocated for tutorials and self-study

- Trainee suggestions for changes to the structure and content of the course
- Trainee views on whether any specific course or lesson objectives were not met
- Adequacy of course instructions, accommodation and catering arrangements.

For each session in the course, the trainee should be requested to allocate a grade, for example:

1 - Excellent
2 - Good
3 - Adequate
4 - Inadequate
5 - Poor

with any appropriate supporting comments for the following aspects:

Content - assess the subject content in the context of the course, e.g., are the objectives appropriate?

Presentation - assess the presentation of the information, e.g., the adequacy of visual aids, instructional techniques, etc.

Handouts - do the handouts cover the lesson content clearly, concisely and in sufficient detail?

For time allocation the trainee should be asked to comment on the adequacy of the allocated time against the actual content. This could be done using the key:

+ : Too much time
o : About right
- : Not enough time

To maximise the information collected from the trainees, the above aspects should be used to construct a questionnaire which should be distributed to trainees at the beginning of a course. Instructors should encourage its completion at the end of each session, while trainee perceptions are still fresh in their minds.

4.6.2.8. Feedback from Instructors

Instructors can contribute substantially to evaluation of training programme effectiveness. Since they have experience in the conduct of training, they can evaluate the duration of particular training modules, structure of the programme, sequence of lectures, quality and quantity of training facilities, and training material accuracy and completeness.

4.6.2.9. Feedback from Performance of Operators on the Simulator

Feedback from operator and crew performance on the simulator during continuing training programs or other simulator demonstrations such as human factors analysis can be useful in assessing initial training program effectiveness. Performance deficiencies on weaknesses identified as common to more than one crew could be caused by incomplete initial training. Results of the continuing training program should therefore be reviewed periodically for possible initial training program implications.

4.6.3. Analysis of Information on Training Programme Effectiveness

The information on training programme effectiveness obtained from sources described above should be analysed to determine what actions are needed to improve the training programme.

There are different methods used for converting obtained information into a training improvement action plan.

First, the frequency of observed problems (e.g., similar comments from different trainees) must be determined to separate occassional occurrences from systematic ones. Frequency distributions or other statistical methods may be used for organising, summarizing and displaying this data. The results would then show how often particular events have occurred, and can be used for comparison with pre-established standards.

The analysis of collected and organised data should be directed to determine the following:

- Does the competence acquired in training meet established standards?
- Does the training programme include all items necessary to meet learning objectives?

The tasks for which performance is below standard require the corresponding training modules to be investigated to determine the causes for the observed poor performance.

Plant operating, maintenance and industry-wide experience can be analysed by this method. Special attention should be paid to the frequency of events indicating below-standard performance. Frequent errors by operations personnel should demand a prompt investigation of the cause.

Another aspect of analysis of collected feedback data is related to the content of the training programme, i.e., analysis of whether the training covers all items needed to meet learning objectives. If it is detected that some items of importance for the trainees' job are missing from the training programme (this would be most likely to occur due to plant changes, modification of plant documents, new plant or industry experiences or new regulatory requirements), the training programme should be supplemented accordingly.

In cases when the collected data on graduates' performance indicates deficiencies, it is essential to identify root causes for such performance problems. Both training and operations management should be involved in the analysis of possible root causes leading to poor performance. In general, the following sequence should be applied:

- Identify specific symptoms of the problem
- Determine possible alternative causes of the problem
- Investigate each alternative cause until it is eliminated or confirmed.

This activity requires experienced analysts. The first two steps are performed by the operations and training management personnel themselves, while the third is accomplished through interviews and discussions with ex-trainees and by directly observing their on-the-job actions.

The accurate identification of root causes allows the selection of appropriate corrective actions (such as better training in the classroom, in the simulator or on-the-job, or a better trainee assessment system). However, it should be recognised that not all plant performance problems are necessarily due to shortcomings in the training programme. Incorrect procedures (both operational and maintenance), inadequate quality control and equipment design faults are other possible root causes.

It is important to emphasise that efficient evaluation of training programme effectiveness can be achieved only with close cooperation between the training department and plant operations management. The systematic evaluation of a training programme is essential to maintain its quality.

4.6.4. Corrective Actions

In cases when plant employees, after completion of their training, do not meet the required performance standards, changes to the training process must be introduced. These may relate to changes in implementation of the existing training programme (better conduct of training, more in-depth trainee assessment) or in changes to training programme content.

Since formal changes to a training programme are costly and time consuming, they must be well documented and processed accordingly. Each utility should establish a procedure for deciding whether or not a training programme should be changed and, if so, how it should be changed and to whom the new or modified training should be provided. Any changes made to training programmes should be accomplished in accordance with established quality control procedures.

The initiative for changing the training programme should be documented by the originator (a person from training or from plant operations) and approved by training and operations management. The implementation of a major training programme change, if approved, should be processed similar to the original training programme, i.e., should include analysis, design and development. Minor changes in training programme content caused by some changes in plant systems and procedures could be implemented directly using a simplified procedure.

4.6.5. Summary

- Evaluation and improvement of training programme effectiveness should be considered as a continuous process of essential importance to maintaining the required quality of training. Without evaluation, the training programme effectiveness would probably deteriorate, and this deterioration would not be detected.

- The first step in evaluating the effectiveness of a training programme is to collect information from appropriate sources.

- The sources of information relevant to indicating training effectiveness, efficiency and any necessity to introduce changes in training programmes are:

  . Feedback from operating plant experience
  . Industry-wide operating experience
  . Reports from plant inspections and evaluations
  . Plant modifications and changes in plant procedures
  . Feedback from job supervisors
  . Feedback from graduates' on-the-job experience
  . Information from trainees after training is completed
  . Feedback from training instructors.

- The collected data on training programme effectiveness should be organised to obtain the frequency of occurrence of particular events (this could, for example, be the repetition rate of employees errors) and other quantitative indicators needed for training evaluation.

- The criteria for evaluation of training programme effectiveness are related to performance standards established by the plant management. An aim of evaluation is also to check that training programmes include all plant changes and changes to plant procedures.

- Some plant and procedure changes will necessitate modifications to simulator hardware and/or software.

- Evaluation requires close cooperation between the training department and plant operations management.

- An essential part of training programme evaluation is identification of root causes of performance deficiencies. This could be done by identifying the specific symptoms of the problem, determining possible alternative causes of the problem and investigating the alternative causes until they are confirmed or eliminated.

- On the basis of the analysis of collected data and of established root causes of performance deficiencies, an action plan to improve and correct the training programme should be initiated. This may consist of improvement in the conduct of training or in changes to the training programme.

- Implementation of changes in a training programme should be well documented and should follow the procedure established by the utility.

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4.7. MAINTENANCE TRAINING

Highly qualified and competent maintenance personnel are essential for ensuring nuclear power plant safety and reliability. A significant percent of the root causes of incidents and accidents in nuclear power plants have been associated with maintenance-related activities. For these reasons, a section of this Guidebook is devoted to an overview of maintenance training, in order to emphasize the importance of training for this critical category of nuclear power plant personnel using a systematic approach.

Correct and timely performance of maintenance work helps ensure safe and reliable plant operation. Maintenance training should aim to develop an awareness of the impact which the worker's actions have on personal safety, plant safety and reliability. Training should develop a clear understanding of the potential impact of maintenance actions on plant conditions and operation, and knowledge of conditions that might compromise safe and reliable plant operation. Maintenance department policies, procedures and philosophy should foster a questioning attitude on the part of maintenance personnel.

Training programmes should be developed for each maintenance discipline - mechanical, electrical, instrumentation and control. The training programmes should be based on the systematic approach to training model presented in Chapter 4. of this Guidebook. Hence, job analysis (see Section 4.2.3.) to define the specific tasks assigned to a position is necessary, and task analysis (see Section 4.2.4.) should be used to define directly-related knowledge and skills. Analysis results should be used to establish the training programme learning objectives, test items, instructional methods and training settings, e.g., classroom lecture, laboratory/workshop, on-the-job training (see Section 4.3.3.). Performance measures used to evaluate employee's performance and to assess training effectiveness can also be derived from the analysis results.

After learning objectives and job-related performance measures are established for a maintenance training programme, the training materials can be developed. These materials should include instructor lesson plans, training aids, text, handouts, performance checklists, examinations and evaluation guides for the selected instructional methods. Section 4.4.4. describes these activities in more detail. Of particular importance in maintenance training is the use of models and mock-ups. The latter, in particular, permit the training and rehearsal of maintenance skills and procedures (see Section 4.4.4.4.). An example of the facilities and equipment provided at a training center in Japan is given in Appendix R.

Methods for the conduct of sessions in the training settings referred to above are described in Section 4.5.

The training programme should be evaluated regularly, as described in Section 4.6., and should determine the extent to which the established objectives are being accomplished. The results of these evaluations should be used to improve training plans, organization, facilities, programmes, materials and procedures. In addition, a systematic method should exist to update the training programme content as a result of plant modification, operating experience, procedure changes and changes in job requirements, such as might be necessary following the introduction of new technologies or techniques.

The goal of initial training and qualification is to ensure that maintenance department personnel possess the physical attributes, knowledge and skills necessary to perform assigned duties in a manner that promotes safe and reliable plant operations. However, it is also necessary to refresh and update these skills by means of continuing training (see Chapter 5), whose main goal is to provide assurance that maintenance department personnel have the required knowledge of applicable plant physical and procedural modifications, changes to regulatory requirements and lessons learned from industry and in-house operating experience that could affect their job performance. Improvements in job performance and the development of broader scope and depth of job-related knowledge and skills are also goals of a meaningful continuing training programme. Another important function of the continuing training programme is the introduction of new technologies and techniques.

Examples of outlines of maintenance training programmes are given in Appendix H.

Chapter 5

A SYSTEMATIC APPROACH TO CONTINUING TRAINING

5.1. INTRODUCTION

Continuing training is that training necessary to maintain and enhance the competence of nuclear power plant staff. It can also include training to improve the career development potential of selected individuals.

It is well-known that the skills and knowledge acquired in initial training gradually deteriorate, especially those which are not regularly used in the actual performance of the job. Nuclear power plant operation is characterized by lengthy periods of continuous normal operation, in which only a limited range of operator action is necessary. Abnormal or emergency situations, when the operator's full knowledge and diagnostic skills are indispensible, are rarely if ever experienced. Continuing training is essential in order to maintain the required level of competence for dealing with abnormal and emergency situations. Simulators or simulated environments play an important role in this type of continuing training for control room operations personnel.

In addition to abnormal and emergency situations, there are many other tasks and individual knowledge and skills included in the objectives of initial training but infrequently used. These can be identified from a job and task analysis and also require continuing training. Examples include not only knowledge items, but also some infrequent equipment repair work which may be of essential importance for plant availability, dose reduction and refueling activities.

Owing to the ongoing development of reactor technology and the experience gained during plant operation, the design of each plant and its procedures will be modified and improved. Therefore, to maintain the required level of competence, an effective continuing training programme must include the updating of previously qualified personnel in those areas relevant to their job functions. Most important of all, many personnel performance problems can be reduced or corrected through continuing training, and lessons learned from incidents and events (at the plant and at similar plants) can be communicated to personnel through continuing training.

It is important to consider all these factors as objectives in a continuing training programme.

Continuing training is not only safety-related but also reduces costs, because it leads to increased avoidance of incidents and accidents, decreased downtime and personnel accidents, and increased personnel motivation and incentive for outstanding as opposed to adequate performance. On the other hand, the overall effort in time and in human and financial resources for a continuing training programme is very significant, especially for the shift operating staff. Therefore, the integration of continuing training programmes into the normal operation and maintenance activities requires considerable attention by plant management. An overview of an SAT model applied to continuing training is given in Table 5.1.-1.

As shown in Table 5.1.-1, the scope of a continuing programme can be subdivided into two main areas:

- Training activities required to maintain competence.
- Training activities carried out to enhance competence.

TABLE 5.1.-1 SYSTEMATIC APPROACH TO CONTINUING TRAINING - AN OVERVIEW

Task	Maintenance of Competence	Enhancement of Competence and/or Career Development
<u>Scope</u> of continuing training programme	- Maintenance of defined standards of knowledge and skills - Ensuring awareness of modifications and changes - Ensuring awareness of lessons learned - Correcting performance discrepencies - Ensuring level of teamwork and diagnostic skills	- Provision of training for career development - Stimulating the introduction of new techniques - Providing a forum for discussion on recommendations for plant improvements - Enhancing intellectual knowledge
<u>Training needs Analysis</u> Review initial training items operating records, etc. and select items for continuing training	Review of: - Initial training items for those which tend to be forgotten and those which are complicated and rarely used - Operating records - QC results - Modifications of plant and procedures - Regulatory requirements	- Select candidates for promotion - Select topics for continuing training programme the may be useful for promotion
<u>Design and Development</u> of training plans and materials. Choice of participants, teachers, methods, materials,training centres, intervals and duration	- Training plans giving subjects, dates, places duration, methods, teachers and materials.	- Selected courses for career development. - Installation of job-rotation programme

TABLE 5.1.-1. (continued)

Task	Maintenance of Competence	Enhancement of Competence and/or Career Development
Implementation of continuing training organization, performance and documentation of continuing training	- Performance of continuing training according to the training plan and documentation of participation, results, definition of knowledge discrepencies.	- Performance of continuing training measures for career development and introduction of new technologies. Documentation of such measures.
Evaluation and Feedback Evaluate examinations of participants. Evaluate worker performance improvements	- Special attention and training given to participants who have performance discrepencies. - Update continuing training programme according to the experience gained. - Update the methods applied and the knowledge required by the teachers.	- Update continuing training programme according to new technical developments. - Selection of candidates for development.

Those training activities required to maintain competence are mandatory and must be included in a continuing training program for all qualified personnel. Other activities can be included in the continuing training program to improve competence (which is highly desirable) or to develop staff for higher-level positions. This latter additional training is sometimes referred to as promotion training in some countries.

In this chapter the major steps described in the previous chapter, namely analysis, design, development, implementation and evaluation, will be discussed in the context of continuing training.

Because of the importance of continuing training in some countries, guidelines have been issued by the authorities which define continuing training requirements. An example from the Federal Republic of Germany of such a guideline is given in Appendix S.

5.2. SCOPE OF A CONTINUING TRAINING PROGRAMME

The aims of a continuing training programme may be defined as:

- Maintenance of job-related competence
- Enhancement of job-related competence
- Improvement of career development potential

5.2.1. Maintenance of Job-Related Competence

Job competence is maintained by:

- Maintaining the required knowledge, intellectual abilities and manual skills related to plant operations and administrative procedures, thereby preventing deterioration of performance

- Ensuring an adequate awareness of plant modifications, procedural changes and regulatory requirements

- Ensuring an appropriate awareness of lessons to be learned from the experience of their own and comparable plants

- Correcting performance discrepancies

- Ensuring the necessary level of teamwork and diagnostic skills.

5.2.2. Enhancement of Job-Related Competence

Job-related competence can be enhanced by:

- Providing training opportunities which may utilize new training methods or training aids as a means of improving job-related competence

- Stimulating the introduction of new technologies and techniques

- Providing a forum for the discussion and recommendation of ways to improve plant performance

- Enhancing intellectual abilities and manual skills particularly in relation to transients and emergencies which can, in continuing training, involve all operating team members.

5.2.3. Improvement of Career-Development Potential

It is important for maintaining personnel motivation and performance that there exists the possibility for career development within the plant and/or utility. This requires that operations personnel be provided with opportunities for gaining new knowledge and skills which, together with carefully planned job rotation, provide the qualifications and experience for them to advance in their careers. These considerations apply both to personnel at the professional and at the technician levels.

5.3. TRAINING NEEDS ANALYSIS

In determining the topics to be included in a continuing training programme, the following items should be considered:

- Initial training topics
- Operating and performance reviews
- Plant and procedure modifications
- Personnel development needs

5.3.1. Review of Initial Training Topics

Based on the job and task analysis, initial training topics should be reviewed to determine which tasks and their associated knowledge and skills should be included in the continuing training programme.

The following criteria for selection should be applied:

- Review of science and engineering fundamentals (e.g., applied thermodynamics, fluid dynamics, reactor physics and kinetics) should be undertaken over a number of continuing training programmes. The use of much of this knowledge in day-to-day operations is limited. This review, when performed in conjunction with plant system training and simulator training, is beneficial in maintaining and improving capability in both diagnostic and cognitive skills (analysis, synthesis and evaluation).

- Operational procedures which are rarely used (abnormal and emergency procedures) should be reviewed periodically. It may also be beneficial to include some infrequently used normal operating procedures, e.g. plant startup, if certain procedures have not been used recently or if improvement in operating performance is required.

- Maintenance procedures which are rarely used. Within this category consideration should be given to those which are associated with work in high radiation fields, (e.g., steam generator tube inspection/repair), those related to work on complicated plant components, possibly involving the use of special tools, and in-service inspection activities.

- Review of topics covered in general employee initial training. This includes personnel safety, radiological protection, site regulations, emergency arrangements, fire protection and first aid.

- Severe accident management. The procedures to be followed in the event of a severe accident should be reviewed and practised in the continuing training programme.

5.3.2. Operations Performance Review

A systematic review of recent operational experience and staff performance at the plant should be included in continuing training. This should include discussion on performance discrepancies and their causes. The review should also take into account deficiencies identified by QA/QC.

Continuing training should also include preparation of staff for future scheduled operations and maintenance activities to improve the preparedness of staff.

Operational review of experience of similar plants through the use of incident reporting systems can identify topics for inclusion in continuing training programmes. All utilities should have a formal system for receiving and reviewing reports from other plants (e.g., the IAEA Incident Reporting System (IRS)) and for directing reports, as needed, to the relevant experts and to the training sections of relevant plants.

Results of reviews, inspections and audits by external bodies, such as the regulatory authority or IAEA OSART team, should be considered for topics to be covered during continuing training.

TABLE 5.3.-1. FORMAL CONTINUING TRAINING NEEDS OF NUCLEAR POWER PLANT OPERATIONS PERSONNEL

Continuing Training Subjects	Managers and Technical Specialists	Shift Supervisors and Operators	Maintenance Engineers and Technicians	Maintenance Craftsmen	Technical Support and Monitoring Staff
	Required Participation				
Science Fundamentals:	-	x	-	-	-
Engineering:					
General technical subjects	-	x	x	x	x
Plant-specific technical subjects	-	x	x	x	x
Plant Operation:					
Operation and emergency features of the plant	x	x	-	-	-
Plant-specific rules, regulations and procedures	x	x	x	x	x
Relevant Topics:					
Modifications of plant design and procedures	-	x	x	x	-
Lessons learned from incidents and operations review	-	x	x	-	-
Management, Supervision and Administration					
Management and supervisory skills training	x	x	x	x	x
Organizational and administrative matters	x	x	x	x	x
General Employees Training:					
Industrial safety	x	x	x	x	x
General plant safety regulations	x	x	x	x	x
In-plant and emergency skills	x	x	x	x	x

5.3.3. Plant and Procedure Modifications

Changes in plant systems design and in plant operating and maintenance procedures due to the following must be communicated to the staff through a continuing training programme:

- Improved procedures.
- Revised standards.
- Plant systems modifications.
- Introduction of new techniques and technology.
- Regulatory authority requirements (changes in manning levels, requalification/relicensing frequency).

5.3.4. Career Development

To facilitate a supply of qualified staff for more senior positions, utilities may consider the selection of an appropriate number of staff to undertake training which will enable them to be considered for promotion. This can be achieved through the use of job rotation and the use of training courses which could be technical, managerial or supervisory in nature. Some utilities find it beneficial to train and authorise a small number of staff to undertake the duties of the post above their present one. Such staff provide 'cover' for more senior colleagues in the event of sickness and holidays, and may supervise contract personnel during outages. This practice also enables management to review performance in the more senior position as an aid to manpower development. Training for career development of selected personnel can be partially accomplished through continuing training.

5.3.5. Subjects not Suitable for Continuing Training

It should be remembered that many subjects which have to be covered by initial education and training should not be repeated during continuing training, as the participants may become bored and lose interest and motivation for continuing training. In general, those subjects which are reinforced through day-to-day work performance should not be repeated. For example, although initial training is necessary, reactor operators usually need no retraining on the operation of systems which they operate very often or on procedures that are used very frequently. Theoretical subjects must be selected with much care. Subjects that improve the understanding of processes that take place in the plant (such as reactivity and thermodynamic characteristics) are of great importance and must be included, while theoretical subjects which are not strongly related to the scope of continuing training as defined in Section 5.2 should be omitted.

5.3.6. Output of the Training Needs Analysis

Having decided upon the topics to be included in the continuing training programme, the methodology of Chapter 4 should be applied to determine the associated skills and knowledge for each topic. In some instances the documentation produced by the initial JTA can be utilised. These skills and knowledge will be utilised in the design phase. Table 5.3.-1. provides a matrix which indicates the continuing training needs for various groups of nuclear power plant operations personnel.

5.3.7. Special Factors Relating to Continuing Training for Different Groups of Staff

5.3.7.1. Managers

Managers maintain competence in their principal management and administrative responsibilities to a large extent by performing their day-to-day duties. Thus, managers would not in most cases be required to receive formal continuing training in these areas on a regular basis, because they would normally maintain their competence by dealing with various technical and administrative issues and solving problems associated with their tasks and functions. Furthermore, they take part in meetings, conferences and working groups and carry out self-studies in relevant areas when necessary. However, they can provide an example to the plant operating and maintenance continuing training and by providing relevant continuing training.

Some kinds of continuing training are recommended for management staff, and thus a formal continuing training programme should be in place for the following:

- Standard programme for emergency drills (fire fighting, radiation emergencies).

- Periodic participation in simulator training sessions designed to maintain their knowledge of plant dynamics and system/system interactions under a range of normal, abnormal and emergency conditions.

5.3.7.2. Control Room Operations Staff

Since the control room operations staff has the most direct impact on safe and reliable plant operation, their continuing training programme has to be reviewed on a regular basis to ensure that the content of the programme addresses actual needs. The various tasks of these personnel can be analyzed for training requirements with a significant degree of accuracy based on the operations procedures, observed performance discrepancies from plant operation, simulator training and reported incidents. The content of this programme should be a tool for motivating and striving for excellence in plant operation.

For this group of staff, the training needs analysis described above should be performed using the SAT method of Chapter 4. The continuing training programme for this group is normally the most extensive. Since the job functions of operations staff are similar in many plants, review of the continuing training programmes of other plants will be helpful in defining the continuing training programme for one's own plant. In addition to the continuing training needs defined in Table 5.3-1, operations staff have to maintain their competence in the following:

- Team skills and communication
- Diagnostic skills
- Performance under stress.

5.3.7.3. Maintenance Staff

The elements which need to be included in the continuing training programme for maintenance staff can be defined by use of the needs analysis approach described above using the SAT method. In some instances, external courses such as those provided by manufacturers will be utilised. However, the overall duration of such a programme will be significantly less than that required for direct operations staff. In addition to the continuing training needs defined in Table 5.3.-1, maintenance staff (engineers, technicians and craftsmen) have to be continually trained in the following areas:

- Welding requalification
- Training on mock-ups
- Trouble-shooting techniques
- Use of safety equipment.

5.3.7.4. Technical Support and Monitoring Staff

Information about plant and procedure modifications, modification of authority regulations, lessons learned from incidents and the implementation of new technologies should be transmitted to technical support personnel. Information should always be job-related, to avoid a flood of irrelevant data.

At the professional level of engineer/scientist, self-study associated with their work on day-to-day problems provides much of the remainder of the training necessary for maintaining and enhancing their capabilities. Attendance at meetings, conferences and specially organised seminars should also be utilised as a means of updating this group of staff. The professional staff also have a responsibility for communicating appropriate topics at a suitable level to the technicians within their departments.

Formal continuing training needs for technical support staff includes emergency drills and general employee training (see Table 5.3.-1).

5.4. DESIGN AND DEVELOPMENT OF A CONTINUING TRAINING PROGRAMME

Design of a continuing training programme uses as an input the list of topics derived from the training needs analysis. Although design and development activities utilise the methods presented in Sections 4.3. and 4.4, there are a number of aspects which are specific to continuing training.

5.4.1 Training Methods

In continuing training, both the scope and use of the traditional training methods require some adjustment.

A continuing training programme should be subdivided into

- Classroom lessons: fundamental subjects, operations review, general employee training

- Simulator training: operations performance, teamwork and diagnostic skills

- On-the-job training and plant drills: performance-oriented subjects

- Laboratory/workshops: mechanical, electrical, chemical and I&C-related skills

5.4.1.1. Classroom Lessons

In continuing training, the participants will be trained in many of the topics presented during initial training, and hence should be able to recall many facts. Therefore, a different approach is required by the lecturer if he is to motivate the participants. The content should be based on case studies; the theoretical background and the relevant facts should be recalled and stressed in connection with actual problems of plant design and plant operation. The active participation of trainees should be promoted by making greater use of oral questions and discussions. At the same time these lessons may serve as a forum for discussion of relevant technical problems. Proposals for technical modifications suggested by the trainees should be evaluated with much care and implemented, if they are beneficial for the plant. If handled in this way, the lecture series will improve the motivation of the staff. Furthermore, if the lessons are perfomed by plant engineers or specialists trained in instructional skills, the cooperation between the direct operating staff and the engineers working in support functions will be improved.

Since the motivation of the staff to attend lessons can deteriorate with time, the delivery and content will affect the motivation of the audience.

Classroom lessons (also referred to as a lecture series) are mainly used to keep the direct operating personnel acquainted with plant and procedure modifications and operations review. Examples of the contents of continuing training programmes for the operators of a nuclear power plant, taken from the Federal Republic of Germany, the United States of America and Yugoslavia, are given in Appendix S.

Compared with former continuing training programmes, subjects such as thermohydraulics and fluid dynamics have gained in importance. This is due to the incorporation into continuing training programmes of the results of the systematic approach to training, the lessons learned from accidents such as TMI and Chernobyl, and the evaluation of operator errors. Furthermore, in a modern continuing training classroom lesson, the detailed explanation of event-oriented emergency procedures may be reduced in favour of the demonstration and discussion of symptom-oriented procedures and mitigation strategies. This is good preparation for simulator training, since it enhances the improvement of diagnostic skills and the ability of the operations staff.

Each lesson of the standard lecture series should be repeated periodically. In general, a period of two to three years has proven to be appropriate, but for certain subjects this period may be extended somewhat. Appendix T identifies these subjects by (-).

The choice of subjects for the annual training programme should be influenced by the evaluation of the previous continuing training period and by deficiencies discovered through the evaluation of the performance of the personnel. Fundamental subjects provided for employees involved in day-to-day duties have to be strictly application-oriented. This enhances their understanding of the tasks involved in day-to-day performance and their diagnostic skills. Presentation of fundamental subjects of general interest normally demotivates the participants.

The compulsory portion of the lecture series for operating personnel should be strongly related to those subjects which are safety and accident related and which require a high level of proficiency to ensure the safe and reliable operation of the plant. The schedule for these subjects should be coordinated with the simulator training programme.

5.4.1.2. Operations Review Sessions

Another main part of continuing training should be operations reviews on a regular basis to keep the operations staff acquainted with lessons learned from incidents and deficiencies which have occurred and modifications in plant design and procedures. In addition to this continuing training objective, an information system concerning significant performance discrepancies and events has to be maintained by the operations management to ensure that operating staff are informed of these developments in a timely manner. Written information which has to be read by each member of the operating staff has proven to be useful. The staff may be asked to confirm this process by signing the information. Based on such a day-to-day information system, operations review sessions (where the issues are discussed in more detail) should be organized every two to three months.

The outline of such a review session should include the following items, which have to be reviewed and prepared systematically:

- Operations review of one's own plant (lessons learned from faults, incidents and deficiencies that have occurred in this plant).
- Operations outlook (special items concerning a scheduled outage of important components or the total plant, load flexibility requirements, special conditions during stretch-out operation).
- Operations review of similar plants (lessons learned from incidents reported from similar plants).
- Reasons for and consequences of modifications to one's own plant design. These sessions are of special importance prior to plant startup following refuelling or other major outages.
- Reasons for and consequences of changes in the plant procedures. These sessions are of special importance prior to plant startup following refuelling or other major outages.
- Results of monitoring of plant operation, including QA deficiencies.
- Results of inspection by governmental bodies.
- Results of QC measures.
- Review of personnel conduct and teamwork performance.
- Review of continuing training programme implementation, both results and evaluation feedback.
- Review of industrial safety performance.

5.4.1.3. Simulator Training

The simulator continuing training programme has to cover three main aspects:

- Maintaining the required level of competence of plant operations personnel as defined for the initial training.
- Training for all significant modifications of plant operation caused by plant or procedure improvements and modifications.
- Intensifying the training in emergency procedures and in handling unforeseen events.

Therefore, continuing simulator training is mostly used by the responsible shift staff, such as the shift supervisor, assistant shift supervisor and reactor operators. Hence, the continuing training programme has to be strictly performance-oriented and the shift staff have to take their normal roles. The content of the programme has to be selected carefully, based on observed performance deficiencies, the lessons learned from previous incidents, interviews with the participants and the outcome of the analysis described in Section 5.3.1.2.

Simulator exercises should emphasise:

- Application of basic operation principles.
- Application of general rules and requirements of plant operation.
- Demonstration of systematic monitoring of plant transients.
- Teamwork and communications.
- Diagnostic skills and problem-solving involving the team.
- Application of plant operating experience.
- Demonstration of leadership in stress conditions.
- Credible multiple failure scenarios.
- Discussions of accident sequences that might progress beyond the design basis with the possibility of core degradation.

Examples of exercises suitable for continuing training on a simulator, taken from the USA, are included in Appendix S.

To make the simulator continuing training programme as effective as possible, it has to be well prepared in advance by:

- Definition and sequence of training scenarios.
- Preparation of the adequate initial conditions (IC).
- Exercise guidance for the instructor.
- Definition of performance standards for each position of the trainee team.
- Definition of the training objectives for each exercise, for each position and for the whole team.
- Preparation of simulator instructor exercise guides (lesson plans).
- Preparation of relevant operating procedures based on those from the nuclear power plant for which the trainees are being trained.
- Preparation of background materials for the exercise debrief session.

A Canadian example of a continuing training module for a specific exercise is included as Appendix T.

The simulator exercise guides should be compared carefully to relevant plant documentation, to ensure consistency and compatibility.

An important element in continuing training is the review of procedures and technical specifications by the operating team. USA guidance on the conduct of such training, which utilizes various training methods in both classroom and simulator settings, is given in Appendix U.

The simulator continuing training for responsible shift personnel should have a length of at least one week per year, and more if possible. The daily programme should consist of simulator exercises preceded by a briefing session and followed by a debriefing during which performance is evaluated (see Section 4.5.9.) using supporting background material.

5.4.1.4. In-Plant Drills

In-plant drills are used to maintain and improve practical aspects of emergency response and to maintain the required level of manual skills.

There are a number of emergency-oriented operations which should be the subject of exercises but cannot be efficiently trained on simulators. These are, for example:

- Fire-fighting drills. These drills should include both the handling of fire-fighting and oxygen mask equipment and the practising of alarm procedures with other plant departments and local fire departments. These drills should take place at least once a year and may also include first aid drills.

- Emergency plant drills. These drills should include the handling of radiation monitoring and protection equipment as well as the practicing of alarm procedures for the case of internal or external radioactivity releases. These exercises should include the cooperation of plant internal and external support groups. These exercises should take place at least once a year.

- Handling of other plant equipment which is rarely in use and has to be activated in case of emergencies within a certain time, such as the refuelling machine, air locks, emergency diesel engines, auxiliary boilers, separate emergency grid connections, etc. These exercises may well be combined with surveillance tests.

- Evacuation of control room following fire or release of toxic gases

- Plant shutdown from outside the control room

- Unexpected plant conditions caused by failures of remote systems, control devices, etc.

Plant drills can be executed on an individual or on a team basis. The sequences of each drill should be defined by scenarios and applicable procedures. The scenarios must reflect realistic plant conditions and should be based on case studies with the aim of minimizing the probability of operator errors in an actual emergency.

The plant drills can be conducted by walkthroughs, by observing actions in emergencies and by demonstrating competence to handle plant emergencies. In particular, the trainee should review plant procedure steps, identify actions required to establish a stable plant condition and identify the relevant control systems' locations. He should also be aware of expected plant instrumentation and alarm responses to specific disturbances.

Plant drill scenarios, as with simulator scenarios, should be carefully prepared to include the clarification of objectives, precautions, terminating conditions, and references. The conduct of a plant drill should not create any condition which could jeopardize plant safety.

It is essential that the implementation of each drill is immediately followed by a critique session in which the details of trainees' performance are reviewed. The session should be used to evaluate individual and team performance, point out weaknesses and indicate necessary corrections.

The performance achieved in drills, and especially any observed weaknesses, should be made known to training and operations management. This information should be used as feedback to expand or upgrade the training as necessary.

In addition to emergency-oriented drills, there are certain maintenance tasks that have to be retrained in order to meet QA-standards, and the requirements of industrial safety and radiation protection, and to maintain the level of skills required for tasks that are to be performed rarely. Examples are given in Chapter 5.3.8.3. The development and implementation of these drills require the active participation of the relevant engineers and specialists of the plant. Since some of these drills are safety-related, a careful assessment must be undertaken.

5.4.1.5. General Employee Training

Continuing training programmes for all employees, including contractor personnel, have been established on the basis of guidelines issued by the relevant authorities (cf (1) in the Bibliography, Section 5.8.) to maintain an acceptable level of performance to meet industrial safety standards and to be able to respond to emergencies.

The subjects of these programmes are directed towards

- Knowledge to improve employees' personal safety and industrial safety and
- Knowledge required to perform certain tasks

As in the example taken from the Federal Republic of Germany (see Appendix V), continuing training programmes may distinguish between different groups of employee and different types of subject, e.g. industrial safety, fire protection, health physics, plant design/organization/access procedures (for non-radioactive parts).

The degree of knowledge required in these subjects depends on the group to which the employees belong. This degree is defined in two categories:

- Sufficient for performing tasks without special supervision
- Sufficient for supervising others.

After having defined groups of employees, subjects and knowledge categories, the general continuing training requirements can be defined for each employee of a nuclear power plant. A possible definition for some typical members of a nuclear power plant's staff is also given in Appendix V. In this case it is assumed that the skilled workers will have to supervise and guide contractor personnel during shutdown or refuelling periods. Therefore, they have been proposed for category 2 in many subjects. Where this is not the case, category 1 may be sufficient.

5.5. IMPLEMENTATION OF A CONTINUING TRAINING PROGRAMME

The implementation of a continuing training programme follows the same principles as those discussed in Section 4.5. of Chapter 4 for the initial training programme.

Special aspects of the continuing training programme identified in the development phase, such as those involving classroom, simulator and plant drills, also need to be taken into account during implementation.

Owing to the experience of the participants in a continuing training programme, the instructor's knowledge of plant-specific operations needs to be greater than that for initial training. Not only do they need to have an appropriately higher technical competence, but also their instructional skills must be developed so that they can conduct satisfactorily the classroom, simulator and plant drill exercises described in Section 5.4.

The satisfactory conduct of continuing training requires the support of the plant management. It is essential that all staff who need continuing training are released from normal duties. Also, to the extent that plant personnel provide continuing training, they too must be allowed time to plan and conduct their presentations.

While continuing training is usually scheduled throughout the year, utilities who do not have ready access to a plant-specific simulator often schedule a period of several weeks for concentrated retraining. This could be undertaken in another country (at a vendor or utility facility) and cover both review of fundamentals and simulator exercises over a period of several weeks on a two-year cycle. In such cases, a member of the plant's training staff should accompany each group of trainees, to ensure that the training meets the plant's needs. Because operations management are not likely to be involved in the conduct of such training, written examinations and reports of individual and team performance should be sent to the employees' supervisor/management. This concentrated retraining does not normally include topics such as specific plant modifications, emergency exercises etc. These, together with plant drills, still need to be undertaken on site.

Assessment of the competence of nuclear power plant personnel should be undertaken by the supervisor not only during continuing training but also while executing normal duties on the job. However, the implementation of a continuing training programme provides an opportunity for more formal assessment of personnel. The assessment should cover all parts of the continuing training programme developed from consideration of the items presented in Section 5.3. (simulator exercises, plant drills, classroom lessons).

Specifically, the assessment for the operations team should include:

- Understanding of fundamentals of plant and system design.
- Knowledge of plant operation including any revised procedures.
- Use of plant documents (procedures, technical specifications drawings, manuals).
- Ability to diagnose events and to decide on corrective action in a timely manner.
- Ability to act satisfactorily as a team member (communication, efficient contribution to joint decisions, issuing or following instructions).
- Ability to meet required station operations standards and standards of professionalism.
- In-depth knowledge of dynamic plant behavior during incidents/accidents and of emergency procedures.

The assessment may consist of written and/or oral examinations and observation of trainee performance during simulator exercises and plant drills.

The method applied for assessing trainee performance during simulator training is similar to the method used in initial training (see Appendix N and appropriate parts of Appendix T). However, the assessment during continuing training requires more active participation of operations management, to ensure expected operating standards are being applied and understood, to ensure uniformity of crew performance and to improve motivation.

Since training on the simulator is conducted for the entire shift crew, it is important to observe closely and evaluate team performance.

When written examinations are used, they should be administered at appropriate intervals. The purpose of such an examination is to reaffirm individual competence in knowledge not covered by simulator exercises or plant drills (e.g., calculations of boron concentration, control rods worth, reactivity coefficients, xenon build-up and its effect on reactivity, hot channel factors, flux maps, core thermalhydraulics, administrative procedures etc.). Oral examinations should take place more frequently and be used as part of the employees' performance evaluation. It can be beneficial to undertake such examinations after a classroom training module or after a set of simulator exercises. In oral examinations, special attention should be given to those areas not evaluated effectively by simulator or written examination (e.g., interpretation of instrumentation response and alarms, weaknesses detected in trainee simulator exercises, precautions needed to execute maintenance activities during plant operation etc).

Questions for use in both the written and oral assessment processes should be reviewed by operations management to ensure that by answering these questions correctly the employees would satisfy the training objectives, which should be based on performance requirements.

Questions should vary to reflect the different job requirements, for example, of the reactor operator and senior reactor operator positions. A trainee's performance during plant drills should be evaluated by an appointed evaluator on the basis of pre-established criteria. Feedback to each employee should be provided as soon as possible after the plant drill in a post-exercise critique session.

5.5.1. On-Shift Performance

Periodic evaluation of the performance of shift personnel during their normal control room duties (and particularly in cases of abnormal operating conditions) should be undertaken by operations management.

All events during plant operation should be reported on a regular and formal basis. These reports also have to be evaluated from the point of view of human failures and weaknesses and, where appropriate, fed into future continuing training programmes.

Detected weaknesses should be analysed and communicated to the training manager with the request to expand or modify the continuing training accordingly in that field.

5.5.2. Performance Below Required Standards

Job incumbents performing below defined standards during continuing training should be removed temporarily from job duties and provided with remedial training and reassessed. If the person still does not meet the required standards, he should be removed from the post. The operating organisation may wish to consider reassigning the individual to a new position for which he could meet the required standards.

5.5.3. Continuing Training Programme Records

Complete records of the conduct of continuing training should be maintained in accordance with the provisions of plant administrative procedures.

The records should include the following information:

- Content of training provided.
- List of trainees who attended the training.
- Examination questions and answers obtained.
- Evaluation of examination results and evaluator observations on each trainee's performance.
- Description of simulator scenarios and plant drills used in training.
- Instructor evaluation of individual and team performance during simulator exercises and plant drills.
- Team performance during emergency evolutions.
- Instructor comments on training programme effectiveness.

The records should be filed and preserved for future use.

5.6. EVALUATION AND FEEDBACK OF A CONTINUING TRAINING PROGRAMME

There are two main aspects which have to be addressed in continuing training programme evaluation:

- The continuing training programme evaluation has to be based on achieved job performance. These indicators should mainly be focused on operation, maintenance, industrial safety and radiation dose received by the staff. The trend of such indicators gives an overall picture for continuing training effectiveness.

- Feedback from participants, instructors, operations management and supervisors should be collected and considered in the development of the next cycle of the continuing training programme. For detailed methodology refer to Section 4.6.2.

- Furthermore, audits of the continuing training programme by QA groups, regulatory bodies and external agencies must be incorporated.

Since the motivation of trainees to participate in training sessions diminishes as time goes by, special emphasis should be given to motivating the participants. Therefore, the opinion of the participants on whether or not they have been motivated by continuing training has to be integrated into the evaluation process. The participants are more critical than those undergoing initial training. They will evaluate their training programme in terms of job relevance and performance orientation. Also, an instructor's performance will be assessed by the participants on the basis of his preparation and presentation of the training subjects. This part of the continuing training programme evaluation makes a valuable contribution to the process of evaluation of programme effectiveness and to the motivation of the participants.

Since the management and the instructors are responsible for the effectiveness of continuing training, it is their task to evaluate the employees' attitudes during job performance and training, to indicate possible causes of weaknesses in the performance of their duties. If any deficiencies are identified, more training may not be the cure for this problem. Instead, the root cause may be the need to improve the quality of the continuing training programme or the attitudes of the personnel. Therefore, the continuing training programme has to be strongly supported by line management in the same way as other normal day-to-day duties.

5.7. SUMMARY

- Since nuclear power plants and their operation requirements will be modified over the years and many of the required tasks can be performed very rarely or never, a continuing training programme for the operations personnel is essential.

- Among other items, the continuing training programme should contain the following:

  . Review of infrequent emergency procedures identified from initial training job analysis.
  . Review of plant and procedure modifications.

- Since the time for continuing training is limited, the programme has to be addressed to the specific needs of the different groups within the nuclear power plant organization. Therefore, several different programmes have to be developed to make the continuing training effective and to keep the participants motivated over the years.

- Management support is of great importance.

- Continuing training effectiveness can be demonstrated by well-defined operation indicators and their trends. A formal incident reporting system can be used to analyze human errors for possible effects on continuing training programmes.

- Management has to support continuing training programmes in the same way as other staff duties and has to relieve the participants from their normal duties so that they can take part in continuing training.

- Any instructor engaged in a continuing training programme has to be highly qualified in his training subjects and in teaching proficiency, because he must train experienced adults in their own field of work.

- Since continuing training is safety-related, expensive and time-consuming, its effectiveness has to be evaluated carefully and continuously. A well-maintained performance-oriented continuing training programme will be one of the main contributors to safe and reliable plant operation.

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Chapter 6

THE FIRST NUCLEAR POWER PLANT: STAFFING AND TRAINING REQUIREMENTS AND PROBLEMS

6.1. INTRODUCTION

Nuclear power poses specific demands for qualified personnel and national infrastructure capabilities that have to be satisfied for any country to achieve success in its introduction and its safe and reliable use. These are a consequence of nuclear power's technical complexity and strict safety requirements. They are especially relevant to developing countries, where a lack of resources or capabilities to meet requirements may constitute the principal constraints to the development of a nuclear power programme.

Problems facing a developing country in the introduction of nuclear power are not insurmountable, as shown by the experience of those developing countries that have already done so. However, the effort required to establish and maintain the competence of nuclear power plant personnel and to strengthen or build up national infrastructures to the necessary levels may exceed available national resources and capabilities or may not be compensated for, or justified, by nuclear power's expected benefits. This would be especially true if it is anticipated that only one nuclear power plant will be needed in that country in the forseeable future. In such cases, a country should most likely delay the decision to launch a nuclear power programme.

Experience clearly shows that many problems in programme development and project implementation can be traced back to inadequacies in:

- Planning and decision-making capabilities.
- Organizational structures (including legal and regulatory frameworks).
- Qualified personnel and the education and training capabilities.
- Industrial support capabilities.
- Financing.

During the planning stage, the major task of a developing country is to identify, assess, and analyse available resources and potential weaknesses, and to devise measures to deal with inadequacies in human resources and in infrastructures. This task has to be performed with objectivity and requires both an in-depth knowledge of the country and expertise in the requirements of nuclear power technology.

Experience indicates that the lack of a sufficient number of qualified personnel usually constitutes one of the most crucial constraints for developing countries seeking to start a nuclear power programme.

6.2. QUALIFIED PERSONNEL

Nuclear power involves an extremely wide range of technical disciplines and skills in practically all conventional areas as well as in specialized nuclear fields. In addition, previous professional experience is usually required to qualify people for most managerial and technical tasks and functions involving major responsibilities. This places a considerable demand on national manpower resources and on the national infrastructures to educate and train qualified personnel. In fact, a nuclear power programme could hardly exist as the only advanced technology in a country with inadequate education, training and other relevant infrastructures.

Some of the most critical and costly problems encountered in the course of implementing a nuclear power programme have been associated with insufficient numbers of, and insufficiently qualified personnel, both professionals and technicians. In many respects the problem is more acute at the technician level. This is due in part to a lack of awareness of the importance of highly qualified, well-trained technicians for the safe and reliable utilization of nuclear power. Another cause is the lower economic and social status and recognition accorded the technician-level occupations in some countries, which reduces their attractiveness and leads good technicians to want to become (sometimes not so good) professional or graduate engineers.

Countries planning and implementing a nuclear power programme tend to associate its success with qualified university-level (graduate) engineers, scientists and administrative personnel, and not with qualified technicians. But it is especially to meet the requirements for such technicians that a country must seek to upgrade its education and training capabilities, utilizing its relevant industrial institutions and infrastructure, as education and training abroad is rarely an option for most technician-level personnel.

In comparison with professional engineers, the quality and quantity of technicians available is far more dependent on a country's level of economic and industrial development, its education and training infrastructures, and its awareness of the importance of, and implementation of, hands-on technical training and experience. It is, therefore, essential that a mechanism exist for close and fruitful cooperation between industry and the system for the education and training of both professional engineers and technicians. This will ensure that the personnel that come out of this system are able to be used by industry, and that they have received practical industrial training as well as the necessary theoretical knowledge.

The critical point is that in all countries which plan to implement a nuclear power programme, the personnel who are to work in this programme must attain a certain level of knowledge and skills, via the upgrading of their basic education and training, to enable them to undergo specialized nuclear-oriented education and training which qualifies them to perform the tasks and functions of the nuclear power programme. Comparable levels of competence to perform a given function/task in a nuclear power programme must be achieved in each country, as it is the function/task which determines the required competence and level of qualifications, and these do not depend on the country or category of personnel - i.e., the level of qualifications and competence must be comparable regardless of whether a higher technician or professional engineer is used to fill a particular position.

Nuclear power requires relatively large capital investments, long lead times, and solid supporting infrastructures. Consequently, there is a need for planning, long-term commitments on a national level, and cooperation involving the government, the utilities, national industry, and scientific, technological, educational and training institutions. Owing to the large overall effort involved in a country's nuclear power programme, policy changes, interruptions, delays or mistakes have proportionately large effects on the programme and may even affect the country's overall economic and industrial development. The role of qualified personnel in planning, directing, co-ordinating and effectively implementing the national effort for the nuclear power programme cannot be overemphasized.

When planning and implementing a nuclear power programme, the cost of good education and training of the required personnel must not be considered as a secondary investment or item for cost-cutting. In recent years, financing and aid institutions have made the financing for training an increasingly important part of the credit/aid package, and this will also be the case for a nuclear power programme, as it is widely recognized that education and training to produce qualified personnel are some of the most essential and critical requirements for safe, reliable nuclear power.

A country deciding to build its first nuclear power plant should certainly have some experience in constructing and operating fossil-fueled power plants. In addition, the country should have industrial infrastructure capability and experience in the production of certain non-nuclear-grade components and in installation works. Also, the country should have some scientific capabilities in nuclear-related activities (nuclear institutes, non-power reactor).

Thus, the likely sources of operations personnel having some of the necessary skills and knowledge for a utility starting the construction of its first nuclear power plant, which probably does not have among its staff personnel with previous nuclear experience (some exceptions may relate to a few individuals with experience in foreign nuclear power plants),would be:

- For operating and maintenance functions: Fossil power plants, merchant ships, navy, local industry.

- For technical services and radiation protection functions: Non-power reactors, nuclear institutes.

- For plant chemistry: Fossil power plants.

- For managers and supervisors: Fossil power plants, high technology process industry.

The selection criteria of operations personnel should be based on the experience of other countries which started nuclear power programs under similar conditions of educational and industrial development.

The recruitment of plant management staff should be completed by the beginning of plant construction, to give sufficient time for training abroad and to secure their return on site at least two years prior to plant startup.

In a developing country, it may be appropriate to employ a larger number of personnel in a nuclear power plant than in an industrialized country, owing to the smaller external support available. Also, in a country that has one or only a few nuclear power plants, there are great difficulties in providing replacements for qualified personnel, and thus overstaffing is advisable. Some overstaffing is also desirable because it provides the opportunity to assign the best candidates (those with the best technical abilities, attitudes, and supervisory abilities) to the most demanding jobs, based on their performance during training.

6.3. INFRASTRUCTURES

Any country for which nuclear power is a viable option must have an electric system of reasonable size and a basic industrial infrastructure, and would thus also have certain technical manpower and education and training infrastructures. These will usually have to be upgraded and adjusted to the particular requirements and problems related to a country's nuclear power programme. It is possible and may be necessary to obtain some highly specialized experts and training from abroad, in particular in the early phases of a nuclear power programme, but this can only be utilized in a very limited way and only in the early phases of the programme. A national manpower development programme is essential.

To develop the personnel and infrastructures to meet the national requirements for the nuclear power programme, a well-planned, co-ordinated and cooperative effort will be needed from the following partners:

- Government (at all levels within the country)
- National education and training system, including technical schools and training institutions and universities
- Special training centres and institutes
- Utilities and industry
- Research and development institutes.

It should be pointed out that, for nuclear power, the need for scientists and research-oriented personnel, particularly in the nuclear field, has often been overestimated, while the need for highly qualified, experienced, and practically-oriented professional engineers, technicians and craftsmen has been very much underestimated.

6.3.1. Industrial Infrastructure

There are no firm rules regarding the industrial infrastructure requirements of a country starting a nuclear power programme but, as a minimum, the plant has to be built, the equipment and components have to be installed and tested, and the plant has to be operated and maintained within the country. This means a basic requirement of competent construction and erection firms and of operations and maintenance capabilities. The available industrial infrastructure will probably not have all the technology, know-how, level of quality, or expertise necessary for nuclear power, but, as is shown by experience, these can be acquired.

Nuclear power places special demands on the industrial infrastructure:

- Highly technical capabilities and knowledge of advanced technology is involved.
- Very strict quality assurance and quality control standards have to be met, owing to nuclear safety and reliability requirements
- Schedules must be complied with
- Many supply items are of unique design
- Cost should be at reasonably competitive levels
- Unfamiliar industrial standards might have to be applied
- Many special materials new to the industry are used
- Equipment and components of unusually large sizes and weights have to be handled and transported.
- Complex equipment requires special testing, maintenance, and repair capabilities.

A country which has decided to start its first nuclear power project cannot successfully accomplish this task if manpower development is limited only to the utility and the government regulatory organization. A country depending completely on imported equipment and industrial services and having no independent local expertise to evaluate plant performance is not qualified to start a nuclear power programme.

Training for personnel working in industry is also needed, to upgrade skills and knowledge in the following areas:

- Quality control and quality assurance in producing and installing nuclear-grade components.

- In-service inspection techniques needed for inspection of nuclear power plant components.

- Environmental qualification of produced equipment.

The utility operating a nuclear power plant needs the support of local industry for:

- Assistance in maintenance activities.

- Performing equipment in-service inspections.

- Performing materials and equipment analysis.

The existing industry is usually unable to supply the materials, equipment, components and services without first improving its capability. This will require the upgrading of quality assurance and quality control, acquisition of new technology, installation of additional equipment and changes in methods and procedures.

In the case of a developing country, it may be difficult to obtain qualified maintenance contractors in the country. One possibility is to use the local contractors who worked on the plant construction (usually as subcontractors to the reactor vendor). However, some activities will necessitate the employment of foreign contractors.

As the industrial infrastructure develops to meet the requirements of the nuclear power programme, it becomes better equipped not only to provide industrial support but also to provide relevant industrial training opportunities and experience. This requires increased co-operation between industry and those educational and other institutions providing university-level education for nuclear power, as well as the most effective use of such resources, for their mutual benefit.

6.3.2. Education and Training Infrastructures

Providing qualified manpower for nuclear power will place new demands on the education and training infrastructures. The problems of some developing and even industrialized countries regarding the education and training requirements for nuclear power have been primarily associated with the limitations of their universities, training institutions and/or industries to provide the resources and capabilities needed to achieve the scope and quality of these requirements.

Curricula must be carefully examined and formulated so that there is a coupling of scientific and technical knowledge with the needs of nuclear power technology, including an appropriate balance between theoretical knowlege and practical training and experience. Otherwise, it cannot be assumed that an academic degree is a reliable measure of quality with respect to the ability of an individual to accomplish a specific task. This is a fundamental problem which should be carefully examined in each country's educational system, if realistic progress is to be made in effective long-term development of personnel for nuclear power.

Two especially important tasks to which adequate attention and resources must be devoted from the outset are (1) the education and qualification of teachers and (2) co-operation between universities and industry to ensure the provision of practical on-the-job experience in industry, including the organizational, contractual and administrative aspects of managing large projects, as universities do not have sufficient capabilities for this.

Adequate national capabilities will have to be developed, particularly at the technician and craftman levels, as technicians and craftsmen constitute an essential component in the viability of a nuclear power programme. Many critical problems are associated with the difficulties of the national education and training infrastructures to provide adequate basic education and training, especially in engineering, physics, chemistry and mathematics. Also, there is a need for more and better practical training in the educational system and in industry. To develop the skills needed domestically, the establishment of a national training centre may be necessary.

Some developing countries have tried to compensate for weaknesses in their educational system by requiring higher educational degrees for some plant positions (even doctoral degrees). This generally will not solve the main problems, since the weaknesses of such education systems are in most cases related to the poor practical training and skills acquired, and not to insufficient theoretical knowledge.

A country will often find it necessary to introduce post-graduate specialization courses to supplement the education and training of graduates who possess non-nuclear education qualifications and (in some cases) professional but non-nuclear experience and who are to work in a nuclear power programme. These specialization courses are not meant to replace the longer-term need for nuclear-related undergraduate and post-graduate engineering and science education and training provided by upgrading relevant parts of the education and training infrastructures. Nevertheless, as a mechanism for the near-and medium-term upgrading of qualifications and for providing new/updated theoretical knowlege and practical skills in nuclear subjects, the specialization courses will have an important role in the national education and training infrastructures.

Although the formal aspects of the technical education systems in many countries are similar, large differences in the actual knowledge and skills of graduating students have been observed. In developing countries, the technical abilities developed by the education system are sometimes limited for the following reasons:

- The lack of an adequate industrial infrastructure in the country and of an industrial tradition make it difficult to find qualified experienced instructors, especially in subjects related to industrial practices, and to provide students with relevant practical training/experience in industry during their education.

- There is little incentive for the best specialists to transfer their knowledge and skill to students by spending their time in teaching (this is a common problem in both developing and industrialized countries).

- The new technologies introduced to a country through a nuclear power programme (new materials, tools, technological processes, analytical techniques) are not absorbed into the education system until after a considerable time lag.

- The educational facilities in technical schools are often insufficient for conducting adequate practical training, so that the teaching has to be, to a large extent, only theoretical.

- The machines, tools, and technologies used in existing industries are often not applicable to modern techniques. This is especially a problem when vocational and apprentice training are conducted in industry for both technicians and craftsmen.

The level of industrial and technological development of a country has a profound influence on the education and training system and environment. The technical education and training system of a country tends to reflect the level and needs of its industry, although usually with some delay. In many developing countries, there does not usually exist the needed degree of close cooperation between industry and the institutions responsible for technical education and training. Three situations may be distinguished:

- Little industrial development: technical education and training will not be oriented to industry's needs

- Long tradition in a specific industry, e.g. mining and mineral processing: education and training will be adapted to that particular industry but not to other industries

- Industrialized countries: education and training will be adapted to a wide range of industries.

The time lag between industrial development and the response of the education and training system means that, in countries which are in the process of industrialization, the system will not be adapted to the country's needs, especially for education and training below the professional levels. It may also not be fully adapted in an industrial country, where technologies and industries' needs are changing rapidly. However, in the more advanced countries, new technologies are usually incorporated into the education and training system with very little time lag.

The education and training systems of industrialized countries generally differ in two important aspects from the systems in countries whose industrial infrastructure is in the early stages of development. These differences will have an important impact on the ability to recruit and train personnel qualified to work in a nuclear power programme.

- Industrialized countries offer a wide range of education and training for the main types of technical personnel (professional, technician, craftsman): there are qualifications at different levels, especially technician qualifications; there are qualifications in a wide range of subjects; and especially professional education offer different treatments of the same subject.

- Industrialized countries offer education and training which emphasize technological applications and which contain practical instruction and work experience to a high degree.

Thus, the education and training infrastructures for professionals, technicians and craftsmen must be adapted/upgraded to meet the needs and deal with the problems of nuclear power technology - in terms of the scope, level and orientation of the technical knowledge and skills and especially emphasizing practical instruction, training and experience. Local universities and institutes could also provide certain direct support for a nuclear power programme, e.g., by developing expertise in nuclear power plant transient and accident analysis, probabilistic safety assessment, fuel management calculations, stress analysis, following equipment behaviour during plant operation, and qualification of nuclear-grade components used as spare parts.

6.4. SOCIO-ECONOMIC AND OTHER FACTORS

A country embarking on its first nuclear power project is often confronted for the first time with an advanced-technology project which lies beyond its previous industrial experience and which, like many other high-technology projects, has been delayed and encountered other serious problems for lack of qualified personnel.

Effective and efficient personnel management is essential for the correct and timely recruitment of personnel, and for their education and training to achieve the competence needed for working in a nuclear power project, and to enhance the retention of nuclear power personnel. It has generally been found necessary to recruit and train more people than are needed to fill existing vacancies, to cover the rate of training dropouts as well as to meet replacement requirements because of the attrition and migration of qualified personnel.

A critical problem has been the retention of qualified technical professionals for the nuclear power programme, especially those who have had education, training and/or experience abroad. In countries where the nuclear power projects are public sector enterprises with government-level pay scales, highly qualified engineers and technicians may be lured to the private sector or even abroad by the opportunity for higher pay and other incentives. This problem has been due not only to differentials in the conditions of employment, but also to phase lags between the scheduling of the manpower development and the nuclear power programmes, so that people were ready when tasks were not or vice versa.

Thus far, the greatest attention has been paid to the education and training of professional engineers and other professional-level personnel needed for a nuclear power programme, which was in many ways understandable as these personnel are involved in the formulation, implementation and management of the major tasks and functions of the various nuclear power activities and, increasingly, directing the tasks and activities of technicians. This subject has been dealt with in the IAEA Guidebook on Engineering and Science Education for Nuclear Power. The requirements for qualified professionals can also be met to some extent by specialized education and training abroad or by foreign experts.

The quality and quantity of technicians available, however, is far more dependent on a country's level of economic and industrial development, its education and training infrastructures, and its awareness of the importance of, and implementation of, hands-on technical training and experience. Most developing countries have not yet found a satisfactory solution to the problem of developing personnel of sufficient quantity and quality on the technician level. They generally have poorly equipped schools and laboratories and place far too little importance on the need to develop practical skills, to work in laboratories to become well-acquainted with essential equipment and experimental knowledge, and to have hands-on experience and on-the-job training.

Some of the most intractable problems regarding the development of qualified technicans are connected with the social and economic incentives and recognition, or lack thereof, which are associated with the status and occupation of technican, especially in developing countries. Some cultural attitudes, such as the avoidance of working with the hands, constitute further obstacles which result in low social and economic recognition of technicians and low esteem for practical skills and capabilities. This constitutes a subtle but very real barrier to attracting good people and to providing them with the necessary education, training and experience. Thus, a greater emphasis has been placed on theoretical versus hands-on education and training for both professionals and technicians.

For these and other reasons, the status and compensation of technicians in some countries do not provide sufficient incentives for recruiting and retaining those most able to fill these positions. Because of the large differences in salaries and status between technicians and professional engineers in some countries, many highly qualified technicians drop out of their education and training programmes and even their jobs in order to enroll in programmes or courses which would give them the qualifications to become professional engineers.

In some countries there are insufficient numbers of, or inadequately educated and trained, technicians while at the same time there is an overproduction of professional engineers, some of whom are used to do technicians' tasks sometimes without the requisite practical capabilities and skills. Professional engineers are generally not prepared through their education and training for technicians' tasks, and the larger portion of technicians' functions cannot be adequately filled by professional engineers.

The lack of adequate financial compensation and social recognition is very often the reason for poorly qualified and too few teachers/trainers of technicians. Adequate practical training facilities are generally not available. These teachers/trainers should, in fact, have higher levels of qualifications and capabilities than the level of technician which would emerge from that part of the education and training process in which they are involved. Thus, well-qualified teachers/trainers of technicians have the same kinds of incentives as technicians themselves for seeking better-paid and/or more socially recognized technical jobs in other (industrial) organizations, or for further education to become professional engineers.

6.5. *THE ROLE OF GOVERNMENT IN SUPPORTING THE INTRODUCTION OF NUCLEAR POWER* AND THE TRAINING OF QUALIFIED PERSONNEL

Each country has the overall responsibility for the planning and implementation of its national nuclear power programme. Without national participation, it cannot carry out this responsibility. The use of nuclear power may for some time continue to be based largely on technology obtained from advanced supplier countries. However, national participation is an essential element in the development of every nuclear power programme, as there are some tasks and functions in any nuclear power programme and project for which organizations of the country must bear full responsibility. Thus, an important role of government is to define and decide on the nature, level and objectives of national participation and the overall programme to achieve the policy goals. The extent of such participation will depend significantly on the capabilities of the existing infrastructures and on the availability of qualified manpower.

It is in general the government's role to take the lead in establishing the technological and other infrastructures for nuclear power. Depending on the objectives of the national policies and the particular conditions prevailing in the country, this could be done by:

- Introducing nuclear science and technology-oriented curricula in national universities or institutes of advanced science.
- Promoting the establishment of nuclear training centres by appropriate organizations in response to the expected requirements for nuclear power personnel initial and continuing training.
- Promoting technology-oriented applied research and development activities in general.
- Establishing national nuclear research and development institutes and nuclear technology development centres with adequate staffing, funding, facilities, programmes and autonomy.
- Promoting and financing the specialized training of professionals within the country and abroad.
- Concluding international agreements and arrangements for the exchange of scientific and technical information and the transfer of technology.
- Establishing a system of socio-economic incentives to provide motivation for individuals to choose scientific and technological careers in the country (professionals and technicians).
- Providing socio-economic incentives for the education, training and retention of technicians.
- Providing incentives for upgrading the capabilities of relevant industries and technical institutions.
- Encouraging industry-university- research institute cooperation.
- Arranging foreign opportunities for training and experience. For example, hands-on experience with non-power or power reactors can be made available through a bilateral governmental agreement between the exporting and the recipient country.

The development of the industrial, education and training infrastructures needed to support nuclear power is a long-term process which can take years or even decades, depending on the overall level of the country's infrastructures at the beginning of this process, and requires the active support of the government.

The operating organization responsible for a nuclear power plant must develop the capability to perform operational safety assessments (or use consultants qualified to do this). It is also essential that the regulatory organization within the country is in a position to review these assessments on a entirely independent basis. No person involved in the production of safety assessments should be involved in their review by the regulatory body.

It is the responsibility of government to ensure that this principle is strictly adhered to and to foster the development of qualified local personnel to undertake these two (independent) roles, i.e., performance and review of operational safety assessments.

6.6. DEVELOPING QUALIFIED REGULATORY PERSONNEL

The regulatory body is responsible for establishing standards for the protection of the public and for ensuring compliance with those standards. The regulatory body in a country starting its first nuclear power plant faces considerable problems related to the following.

The personnel of the regulatory body are usually inexperienced and their competence may be below what is required.

The codes, standards and design criteria applicable to the first nuclear power plant are usually those valid in the reactor vendor's country. Only part of the codes applied in nuclear power projects are of international significance (e.g., IAEA, ICRP, IEC). Local codes are used if possible for non-nuclear-specific activities (such as civil works, industrial safety) and for environmental protection.

It is likely that the regulatory personnel are not familiar with the codes, standards and safety criteria on which the nuclear power plant design is based, nor with the fundamentals of applied nuclear technology. The lack of knowledge and experience of regulatory personnel has in many instances caused unnecessary delays in issuing permits and thus delays and other problems in plant construction.

However, the regulators are responsible for issuing construction and operations permits to the utility on the basis of their correct understanding and implementation of the relevant codes, standards and safety criteria applicable to plant design and construction.

It is thus evident that considerable attention should be paid to the timely development of the personnel of the regulatory authority in a country starting the construction of its first nuclear power plant.

A number of important resources can be called upon to assist in the establishing and proper functioning of a country's regulatory body. Some of these are:

- Establishing a close cooperation with experienced foreign regulatory bodies, particularly with the regulatory body from the reactor vendor's country, to obtain information on the application of codes, standards and design criteria relevant to the nuclear power plant's design, complemented by information on regulatory requirements, inspection methods, evaluation criteria, operator licencing etc.

- Using the services of international organizations, such as the IAEA, to obtain assistance on safety-related issues.

- Arranging suitable training for regulatory personnel. This training could be partly combined with the training of nuclear power plant operations personnel.

In addition to the above, the regulatory body can use the expertise of specialized local institutions in the decision-making process (nuclear and other institutes, engineering organizations, universities). This approach has proven practical in cases when the regulatory body has had insufficient staff to carry out its responsibilities.

6.7. SPECIAL CONSIDERATIONS FOR OPERATING ORGANIZATIONS

Not only will the first nuclear power plant in a country constitute probably the largest generating unit added to the system, but also, owing to its special features, it will impose unprecedented requirements on the utility, which will have to adjust its organization, capabilities and characteristics to respond to this challenge.

It must be clearly understood that a nuclear power plant is not just another power plant. The organization in charge of the project must be able and willing to undertake the necessary adjustments, changes and developments. Electric utilities may find it very difficult to undertake a first nuclear project, and it may be that they are not interested or qualified to do so. There are examples of countries where the implementation of the first nuclear power plant has not been handled by an electric utility but by a nuclear energy commission or by a new organization especially established for this purpose. Such solutions, however, also imply similar or possibly even larger efforts to be undertaken. Because of lack of experience and expertise, a utility embarking on its first nuclear project will have to rely heavily on outside advice and services. If the nuclear plant is also the first one in the country, the utility will have to rely on advice and services from abroad.

It is highly recommended, therefore, that before a country/utility begins contracting for a first nuclear power plant, an adequate number of professionals receive training to acquire all knowledge and skills needed for the successful negotiation and implementation of effective contracts with vendors, component manufacturers, consulting companies and others. These contracts should include clear, mutually acceptable and binding provisions for the supply of any and all appropriate training of operations personnel, including simulator training, within the framework of, and as an integral contribution to, a training programme based on a systematic approach to training.

The training of personnel for the operation and maintenance of the first nuclear plant is the largest training load of a utility. Within a period of a few years, all plant personnel have to be selected and trained. Subsequent training for the operating plant is more evenly spread out and consists of initial training of small numbers of replacement personnel and continuing training of existing personnel to maintain and upgrade their competence.

Because of the large training load and the utility's lack of experience, the utility must obtain assistance for the initial training of the personnel for the first plant. The services offered by reactor vendors for the training of operators and by component manufacturers for the training of technicians and maintenance personnel should be used and may be supplemented by the services of research and development organizations and of consultant organizations offering training services.

In developing its training programmes, a utility organization in a developing country should probably use the services of an experienced consultant to assist in performing the job and task analysis. Additional problems which could be encountered include the unavailability of qualified training instructors capable of implementing the training programmes. Without competent instructors, a well-developed training programme would not significantly contribute to improvement in personnel performance.

Whatever organizations are used to provide initial training, the operating organization responsible for the operations of a nuclear power plant and for the training of plant personnel should discuss its training programme development and implementation with another utility which has already had experience in nuclear power plant operations, in the training of operations personnel, in the use of consultants, and in contracting for training.

The operating organization should in most cases prepare the plant operation and maintenance procedures. This approach allows the plant to be gradually taken over from the constructors and avoids the difficult situation (especially in the case of the first plant in a developing country) when the operating organization has to take over a complete plant in one step.

A second phase of training begins after the plant has started to operate. Continuing training of the initial crews must begin, and replacement personnel must be trained. The utility is now on its own, and must have its own training organization to meet these initial and continuing training needs, either with its own resources or by using contractors, or by a combination of both. It is essential that the planning of this second phase of training proceed in parallel with the planning of the project; the utility must have the organization, the personnel and the facilities to train its operations personnel from the time of plant startup at the latest.

In the longer term, the utility should consider how it might influence the education system; it should establish good relations with local education institutions and encourage the development of courses specially adapted to the needs of nuclear power plant operations. Education systems are slow to change, and the utility should not expect the system to adapt to new needs without some years of persuasion and preparatory work.

A utility starting its first nuclear power plant has the advantage of not being bound by existing practices and traditions regarding personnel policy matters. It can and should lay down its policy with a long-term view, taking into account the special aspects of nuclear power plants, in particular with regard to the high quality requirements, to ensure safe and reliable operation.

6.8. TRAINING CONDITIONS AND CONSTRAINTS

For the first nuclear project in a country, it is not possible to satisfy the requirements for prior nuclear power experience, and obtaining it abroad may prove to be a most difficult problem. For some positions, the requirements may be limited to fossil power plant experience supplemented by experience acquired during training and during nuclear plant startup and commissioning.

Reactor suppliers generally do not own nuclear power plants, but usually can provide simulator training. If a reactor supplier has a close connection with a utility owning a nuclear power plant, it may be able to convince the utility to offer a few opportunities for on-the-job training at its nuclear power plant for the benefit of the buyer's trainees. It must be recognized, however, that such on-the-job training cannot go beyond being attached to an operational shift as an observer. In no case would a trainee be allowed to operate a plant nor has he the legal right to do so, if not duly authorized.

The utility starting to construct its first nuclear power project, especially if it is the first nuclear project in the country, would have neither an available, useable training programme nor experienced training staff. The expertise needed to start the gradual development of its own training capability should be obtained from abroad.

It is usual first to buy training services from the reactor vendor or, less commonly, from a consulting company. The training programme offered is usually generic, i.e., common to all plants of a particular type. The simulator training is based on an existing reference plant different from the plant of the trainees.

The main problem with this kind of training of operations personnel lies in its non-specific nature. If the training is performed on a non-plant-specific simulator, using generic operating procedures, it qualifies the operators to operate the reference plant, but not their own plant. This is because plant systems analysis, operating procedures, simulator control room layout and simulator design are based on the reference plant design.

The most straightforward approach is for the utility, at the time of purchasing its first nuclear power plant, to buy a plant-specific training simulator, the services of experienced training instructors and training materials developed on the basis of job and task analysis. Such an approach would probably lead to obtaining the best training results. It is recommended that a plant-specific simulator be placed in operation as soon as possible, preferably before plant start-up, if sufficient design data is available for such an approach.

If a non-plant-specific simulator is used, considerable attention should be given to on-the-job training of the plant operations personnel. This on-the-job training concentrates on learning plant-specific features of the trainees' own plant and consists of:

- Development of plant-specific operating and maintenance procedures.
- Operating and maintaining plant systems during plant startup.
- Operations training in a fossil power plant.

The plant staff should develop the plant startup and operating procedures of their own plant on the basis of the reactor vendor's generic procedures. For this work, they must study carefully the systems flow diagrams, systems descriptions, systems layouts, controls and instrumentation diagrams etc. The development of operating procedures gives the operating staff the opportunity to become acquainted with the design of their plant, to analyse and discuss with the vendor's specialists all problems and unclear items, and finally to become fully acquianted with the content of the procedures.

This exercise is extremely useful, especially if their original training was non-plant-specific. It is obvious that such an exercise depends on the timely recruitment and initial training of the operations staff .

In some cases the utility may decide to purchase a complete set of plant-specific startup and operating procedures from the reactor vendor. This is probably not a good practice from the point of view of preparing the operating staff for their duties, unless these procedures are used in training on a plant-specific training simulator.

In a country starting its first nuclear power plant, on-the-job training is of essential importance for operations personnel to reach the required competence. The work of operations personnel during startup provides the opportunity for particularly effective on-the-job training which prepares them for formal authorization and hence to operate the plant after the contractors leave the site.

Maintainance personnel should participate in plant system installation and in the development of plant maintenance procedures. This work is based on generic maintenance procedures provided by the reactor and component vendor and on specific equipment manuals. It is recommended that the maintenance personnel, after completing the required training courses, are assigned to the plant installation and component testing groups, and to the development of maintenance procedures, for the systems they will be charged to maintain. This approach motivates them to learn, discuss with vendor specialists, collect data, documents etc., knowing that the experience obtained will be directly applicable to their work.

In addition, on-the-job training should include a certain period of work in an utility's fossil plant to give opportunity to the trainees to get a feel of the real plant operation, especially in relation to control room activities, operation of turbogenerator plant and coordination with the electric system load dispatcher. On-the-job training structured in this way could partly compensate for the lack of operating experience in a nuclear power plant.

A small utility will have fewer opportunities than a large one for the career development of its personnel. Also, any utility starting a nuclear power programme is small in terms of its nuclear operations and cannot have the scope for the career development of its personnel that is available to a utility which already has a large nuclear power programme.

It is apparent that if there is only one nuclear power plant, the possibility of career development by job rotation is limited by the number of people available for rotation and by the number of positions into which they can be moved. However, the limitations, though real, need by no means prevent the utility from practising job rotation. As noted in the discussion of job rotation, some utilities insist that senior managers shall have a period of work in the direct operating function, including serving for a time as shift supervisor. Clearly, the number of persons occupying posts for career development purposes must be kept to a small proportion, for instance no more than one shift supervisor at a plant should be occupying the position temporarily. Also, individuals rotating into jobs must be fully trained and qualified to perform those jobs to which they are assigned.

Some utilities have to recruit personnel with low-level qualifications from the education system and raise their competence by training and experience, i.e., they substitute training and experience for education. Such schemes are operated by some large utilities with many years' experience of nuclear power plant operation. The size of the utility and of the nuclear programme makes it possible to define the needs and relevant programmes and to implement the programmes. A utility starting its first nuclear power plant should not consider schemes of this type for career development, since it has neither the experience nor sufficient demand for nuclear personnel to make the programme workable. Nevertheless, some large utilities may have developed schemes on these lines for some of their operations personnel on fossil-fuelled plants; it might be feasible for the utility to extend its experience and practice to the personnel for its first nuclear power plant.

6.9. SOURCES OF ASSISTANCE TO MEET THE REQUIREMENTS AND DEAL WITH THE PROBLEMS OF A FIRST NUCLEAR POWER PLANT

A utility involved in preparing for the operation of the first nuclear power plant in the country needs assistance from experienced foreign utilities and companies and from relevant international organisations.

The most frequently used resources of assistance, advice and help are:

- Reactor vendors
- Consulting companies
- Nuclear utilities
- International Atomic Energy Agency (IAEA)

6.9.1. Assistance from Reactor Vendors

Reactor vendors are willing to sell their training services to utilities. This training is normally included in "turnkey" contracts and can also be contracted for in "non-turnkey" contracts. The training is in most cases generic to a group of similar plants. It may, on request, be tailored to a specific plant, but in this case the costs of training would be considerably higher. The advantage of using a reactor vendor's training services is that their instructors usually have good knowledge of and experience with the reactor components and systems of that particular reactor type. This approach is the one most widely used by utilities in countries starting their first nuclear power project. However, vendor-provided instructors may lack operations experience and may be design-oriented rather than operations-oriented.

6.9.2. Cooperation with Other Nuclear Utilities

Cooperation with experienced nuclear utilities is of considerable value to the utility starting its first nuclear power project. Utilities all over the world recognise their interdependence and the benefits to be obtained from mutual assistance. Many countries have an association of utilities charged with promoting the exchange of operations experiences. This is particularly true for nuclear utilities, because of the strong impact of a safety problem or accident in one plant on the whole nuclear power community.

Most of the utility associations and many individual utilities maintain international contacts and specifically arrange for the supply of information to foreign utilities. A most beneficial cooperation is achieved if an experienced foreign utility is operating a similar nuclear plant supplied by the same reactor vendor.

The advice and assistance obtained from such cooperation may consist in:

- Advice on the setting up and conduct of the training programme

- Obtaining copies of plant documentation (FSAR, operating and maintenance procedures, quality assurance plan, training materials, training programmes etc.)

- Arranging on-the-job training during specific plant activities (such as equipment servicing, refueling outages, repair or changes of large components, decontamination works)

- Observing control room activities and the conduct of plant operations.

6.9.3. Assistance from Consulting Companies

Consulting companies also sell training and other services to utilities. The utility will probably need the services of a consultant (especially for its first nuclear power plant). Consulting companies can arrange simulator training in a training centre and provide training in specialized subjects (e.g., risk analysis, fuel management, radiation protection).

To define the need for services and to obtain the best results from service contracts, the utility must have poeple experienced in drawing up the relevant contracts and in controlling their execution. Here again, it is advisable for a utility starting its first nuclear power project to learn from the experiences of other utilities which have used consultants for training and other services.

6.9.4. Assistance from the IAEA

One of the main objectives of the IAEA is to provide international guidance in general, and technical assistance to individual countries in particular. This Guidebook is an example of international guidelines developed by the Agency on training to establish and maintain the competence of nuclear power plant operations personnel. It updates and develops further the guidelines given in earlier IAEA Guidebooks on the Qualification of Nuclear Power Plant Operations Personnel (Technical Report Series 242), and on Manpower Development for Nuclear Power (Technical Report Series 200).

Such international guidelines are subject to certain constraints. They cannot in general be too detailed, because they must be applicable to the large range of countries and conditions represented by the IAEA's Member States.

A utility starting its first nuclear power plant may wish to adopt and apply the Agency's international guidelines to its particular situation. Because of the above-mentioned requirements, problems and constraints, it will find that, in practice, the application of general guidelines to particular situations is not an easy task and it may wish to obtain from the IAEA additional guidance, advice and assistance.

The Agency provides, on request, technical assistance to its Member States. In the area of nuclear power operation, this country-specific assistance has in the past been concentrated mostly on safety issues. IAEA Missions have been involved in the reviewing of safety analysis reports, functions of local regulatory authorities, safety aspects of operator training, plant modifications intended to improve safety (for example, post-TMI action plans) etc. Other assistance has dealt with energy planning, infrastructure and manpower development, contracting, quality assurance and other areas related to the planning and implementation of a nuclear power programme.

IAEA technical assistance is directed not only to utilities and regulatory bodies but also to upgrading the capabilities of local institutes to perform activities such as nuclear plant safety analysis, equipment inspection, quality assurance and environmental monitoring, since these are needed by both the utility and regulatory body.

In the future, training programme advice and assistance teams would be made available on request to Member States for missions of experts who would provide advice and assistance on setting up, implementing, monitoring and upgrading programs for the initial and continuing training of nuclear power plant operations personnel. This Guidebook would provide the guidelines for such advice and assistance, based on a systematic approach to training.

Also, seminars and workshops would be held at the IAEA Headquarters in Vienna and in various Member States for specialists in training and for utility management, to disseminate more widely the Guidebook's information and guidance on the importance of training in a systematic manner, to provide information on good training practices in various Member States, and to promote the necessity for continuing training worldwide as an essential part of the responsibility of management to maintain and ensure qualified operations personnel for nuclear power plants.

6.10. SUMMARY

- The specific demands posed by nuclear power for qualified personnel and national infrastructure capabilities are especially relevant to developing countries, where a lack of resources or capabilities to meet requirements may constitute the principal constraints to the development of a nuclear power programme.

- The effort required to establish and maintain the competence of nuclear power plant personnel and to strengthen or build up national industrial and education and training infrastructures to the necessary levels may exceed available national resources and capabilities or may not be compensated for, or justified, by nuclear power's expected benefits. This would be especially true if it is anticipated that only one nuclear power plant will be needed in that country in the forseeable future. In such cases, a country should most likely delay the decision to launch a nuclear power programme.

- Experience indicates that the lack of a sufficient number of qualified personnel usually constitutes one of the most crucial constraints for developing countries seeking to start a nuclear power programme.

- Comparable levels of competence to perform a given function/task in a nuclear power programme must be achieved in each country, as it is the function/task which determines the required competence and level of qualifications, and these do not depend on the country or category of personnel - i.e., the level of qualifications and competence must be comparable regardless of whether a higher technician or professional engineer is used to fill a particular position.

- It is recommended that the maintenance personnel, after completing the required training courses, are assigned to the plant installation and component testing groups, and to the development of maintenance procedures, for the systems they will be charged to maintain. This approach motivates them to learn, knowing that the experience obtained will be directly applicable to their work.

- In a country starting its first nuclear power plant, simulator training (preferably on a plant-specific simulator) and on-the-job training are of essential importance for operations personnel to attain the required competence.

- The likely sources of operations personnel who have some of the necessary skills and knowledge for a utility which is starting the construction of its first nuclear power plant and which probably does not have among its staff personnel with previous nuclear experience would be, for operating and maintenance functions: fossil power plants, merchant ships, navy, local industry; for technical services and radiation protection functions: non-power reactors, nuclear institutes; for plant chemistry: fossil power plants; for managers and supervisors: fossil power plants, high technology process industry.

- Some of the most critical and costly problems encountered in the course of implementing a nuclear power programme have been associated with insufficient numbers of, and insufficiently qualified personnel, both professionals and technicians. In many respects the problem is more acute at the technician level. This is due in part to a lack of awareness of the importance of highly qualified, well-trained technicians for the safe and reliable utilization of nuclear power. Another cause is the lower economic and social status and recognition accorded the technician-level occupations in some countries.

- In a developing country, it may be appropriate to emply a larger number of personnel (overstaffing), in a nuclear power plant than in an industrialized country, owing to the smaller external support available, the greater difficulties in providing replacements for qualified personnel and the opportunity this provides to assign the best candidates to the most demanding jobs, based on their performance during training.

- A country which has decided to start its first nuclear power project cannot successfully accomplish this task if manpower development is limited only to the utility and the government regulatory organization. A country depending completely on imported equipment and industrial services and having no independent local expertise to evaluate plant performance is not qualified to start a nuclear power programme.

- Effective co-operation is essential between industry and those educational and other institutions providing education and training for nuclear power.

- In developing countries, the reasons why technical abilities developed by the education system are sometimes limited include: a lack of qualified, experienced instructors; educational facilities in technical schools which are often insufficient for conducting adequate practical training, so that the teaching has to be, to a large extent, only theoretical; and inadequate incentives and tradition for, and insufficient appreciation of the critical importance of, acquiring practical skills and experience.

- Most developing countries have not yet found a satisfactory solution to the problem of educating and training personnel of sufficient quantity and quality on the technician level. Some of the most intractable problems regarding the development of qualified technicians are connected with the social and economic incentives and recognition, or lack thereof, which are associated with the status and occupation of technician, especially in developing countries. Some cultural attitudes, such as the avoidance of working with the hands, constitute further obstacles which result in low social and economic recognition of technicians and low esteem for practical skills and capabilities. This constitutes a subtle but very real barrier to attracting good people and to providing them with the necessary education, training and experience. Thus,in some developing countries a greater emphasis has been placed on theoretical versus hands-on education and training for both professionals and technicians.

- For these and other reasons, the status and compensation of technicians in some countries do not provide sufficient incentives for recruiting and retaining those most able to fill these positions. The lack of adequate financial compensation and social recognition also is very often the reason for poorly qualified and too few teachers/trainers of technicians.

- National participation is an essential element in the development of every nuclear power programme, as there are some tasks and functions in a nuclear power programme and project for which organizations of the country must bear full responsibility.

- The development of the industrial, education and training infrastructures needed to support nuclear power is a long-term process which can take years or even decades, depending on the overall level of the country's infrastructures at the beginning of this process, and requires the active support of the government.

- The operating organization responsible for a nuclear power plant must develop the capability to perform operational safety assessments (or use consultants qualified to do this). It is also essential that the regulatory organization within the country is in a position to review these assessments on a entirely independent basis. No person involved in the production of safety assessments should be involved in their review by the regulatory body.

- It is highly recommended that before a country/utility begins contracting for a first nuclear power plant, an adequate member of professionals receive training to acquire all knowledge and skills needed for the successful negotiation and implementation of effective contracts with vendors, component manufacturers, consulting companies and others. These contracts should include clear, mutually acceptable and binding provisions for the supply of any and all appropriate training of operations personnel, including simulator training, within the frameowrk of and as an integral contribution to a training programme based on a systematic approach to training.

- Whatever organizations are used to provide initial training, the operating organization responsible for the operations of a nuclear power plant and for the training of plant personnel should discuss its training programme development and implementation with another utility which has already had experience in nuclear power plant operations, in the training of operations personnel, in the use of consultants, and in contracting for training.

- A utility involved in preparing for the operation of the first nuclear power plant in the country needs assistance from experienced foreign utilities and companies and from relevant international organizations. The most frequently used resources for assistance, advice and help are: reactor vendors, consulting companies, nuclear utilities, and the International Atomic Energy Agency (IAEA).

- IAEA training programme advice and assistance teams can be made available on request to Member States to provide advice and assistance on setting up, implementing, monitoring and upgrading programs for the initial and continuing training of nuclear power plant operations personnel.

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GLOSSARY

Analysis

The training system development phase that assesses performance requirements or deficiencies, determining the needs that are best satisfied through training, and produces task performance data that serves as the foundation for training programme design, development, and implementation.

Assessment

A formal, structured activity through which the knowledge, skills and attitudes of a trainee are determined. The process can be based on oral, written, simulator tests or job performance demonstrations which collectively are used to verify that the competence necessary to perform the job for which the trainee has been trained has been acquired.

Attitudes

The dispositions necessary to undertake a job in a competent and professional manner.

Certification

Formal recognition of successful completion of training by a trainee.

Classroom Training

A training setting in which lectures, demonstrations, and discussions are conducted.

Condition

The circumstances existing prior to task performance.

Continuing Training

That training, after certification, which is necessary to maintain and enhance competence.

Criteria

The standards used to compare and evaluate any performance, product, or process.

Demonstration

A training method in which a procedure is shown in a step-by-step sequence.

Design

The training system development phase in which products of job and task analysis are used to develop specifications for training programme development and implementation: including selecting training settings, determining expected trainee entry-level skills and knowledge, developing learning objectives and tests, and formulating the training plan.

Development

The training system development phase that involves establishment of learning activities, selection of media and methods, review and selection of existing course material, development of new material, and the tryout and revision of course material.

Discussion

A training method involving guided conversation between trainees that encourages constructive thinking and interaction within the group.

Element (Action Step)

A discrete action or step executed during the performance of a task.

Enabling Objective

One of a set of objectives that supports and is required for the attainment of a terminal objective.

Example: /Enabling Learning Objectives - Tritium Analysis Tasks

/Following the lesson and with no further assistance the trainee will:

/- /Set up the Packard 300 liquid scintillation counter
/- /Distill a liquid sample
/- /Measure sample into liquid scintillation vials
/- /Measure scintillation solution into sample
/- /Mix sample solution
/- /Measure sample count rate
/- /Calculate sample tritium activity
/- /Record value of tritium activity
/- /Clean/store equipment
/- /Return references

/in accordance with analytical procedures 1604.003 and 1604.004
(See entry for /Terminal Objective' for associated Terminal Objective).

Entry-Level Test

A test that is used to measure trainee entry-level skills and knowledges.

Evaluation

The training system development phase in which indicators (eg operating experiences, employee performance, job requirements, etc) are monitored, assessed, and used to maintain and improve the performance of a training programme.

Formal On-the-Job Training

A training setting in which plant employees achieve learning objectives through training conducted in the job environment, typically conducted by currently qualified incumbents.

Implementation

The training system development phase in which the training programme is put into operation; includes implementing the training plan, preparing for and conducting training, conducting in-training evaluation, and documenting training.

Job

The duties and tasks performed by a single worker.

Job Analysis

A method used in obtaining a detailed listing of the duties and tasks of a specific job, and information needed to determine which tasks should be included in training.

Job Performance Measure (JPM)

Tests used to evaluate a worker's proficiency.

Knowledge

Understanding of facts, principles, or concepts. Knowledge includes cognitive (mental) processes necessary for applying information.

Example: Required knowledge - Tritium Analysis Task

Knowledge:

- methods for properly and safely handling radioactive samples
- definitions of units of radioactivity
- calculation of radioactivity concentration using instrument
  count rates, sample volume, counting efficiency, etc
- procedure for disposing of radioactive sample materials
- determination of reagents required for analytical procedure
- reasons for distilling tritium sample

Laboratory/Workshop

A training setting in which the conditions of job performance are simulated to permit hand-on application of course material by the trainees.

Learning Activities

Activities of instructors and trainees during training events.

Learning Objective

A statement that specifies measurable behaviour that a trainee should exhibit after instruction, including the conditions and standards for performance.

Lecture

A training method characterized by a public speaking-type presentation that is organized and presented in logical steps.

Lesson Plan

An instructor's primary training document that outlines instructor and trainee activities and the resources necessary for the conduct of training.

Media

The materials used to transmit information to trainees. Includes computer-assisted instruction, simulation and audio and/or visual presentations.

Method

A strategy by which the trainees achieve the learning objectives, includes lecture demonstration/practice, discussion, oral questioning, role playing, walk through, and self pacing.

Module

A single unit of self-contained instruction.

Needs Analysis

A process of identifying potential or existing training needs by examining gaps between performance requirements and existing or expected performance.

Oral Questioning

A training method involving interaction between instructors and trainees that provides a sampling of trainee comprehension of the material.

Performance-Based Training

A systematic programme of instruction designed around tasks and the related knowledges and skills required for competent job performance.

Performance Demonstration

A trainee assessment method for hands-on skills in which the trainee performs the task or skill and whose performance is assessed by a qualified individual.

Performance Standard

Measurable requirements, either quantitative or qualitative, by which performance is evaluated.

Pretest

A test administered to all trainees before beginning a course to confirm individual trainee preparation for entering training; it also is used to identify remedial training requirements and to exempt trainees from all or portions of training.

Pre Exercise Brief

An aspect of simulator training that can consist of classroom-type discussion and/or a walk-through of the simulator exercise or operation of the simulator at real-time (freezing the simulator when appropriate to emphasize operating principles and the basis for actions taken).

Qualifications

The combination of an individual's physical attributes and technical, academic, and supervisory knowledges and skills developed via training, education, and on-the-job experience.

Role Playing

A training method in which the trainee assumes a role in a real or simulated job environment or situation.

Self-Pacing

A type of self-study technique or strategy in which the pace of training is controlled by the trainee.

Self-Study

A training setting without a full-time instructor in which the conditions are provided in the training materials or in the plant when needed by the trainee.

Simulator Training

A training setting using a training device that simulates a plant or a portion of a plant to develop trainee operating skills and to provide knowledge of plant behaviour during normal, abnormal, and emergency conditions.

Skill

The ability of a worker to perform an action requiring coordination of body movements.

Example: Required Skills - Tritium Analysis Task

Skills:

- boiling liquid sample while avoiding splashing
- operation of liquid scintillation counter
- use of pipette to measure liquid sample

Subject Matter Expert (SME)

A worker qualified and experienced in performing a particular task.

System Knowledge

Understanding of information on a specific system and its major component locations, interrelationships, indications, controls, alarms, or power supplies (eg purpose of letdown flow control valve is to control CVCS letdown; location of charging pump running indicators).

Task

A well-defined unit of work having an identifiable beginning and end and two or more elements. Through job analysis each task is defined in terms of an action to be taken, under defined conditions and to the stated standards of performance.

Example: Chemistry Technician Task - Tritium Analysis

Under normal plant operating conditions, perform tritium analysis a reactor coolant sample using equipment and materials normally available in the radiochemical laboratory, perform the analysis in accordance with all applicable procedures.

Task Analysis

The systematic process of examining a task by interviewing job incumbents to identify conditions, standards, elements, and required skills or knowledges.

Task Standard

A statement that defines a measurable criterion or acceptable standard of task performance. The criteria may be stated as time requirements, degree of accuracy, or allowable number of errors.

Terminal Objective

A statement describing a trainee's expected performance after training. Terminal objectives contain job-related conditions, actions, and standards and are supported by a set of enabling objectives.

Example:Terminal Learning Objective - Tritium Analysis Task

Given a liquid sample and necessary tools, equipment, standards and procedures the trainee will perform tritium analysis in accordance with procedures 1604.003 and 1604.004.

Test

A device or technique used to measure trainee mystery of the learning objectives (composed of a number of discreet test items and questions).

Training Methods

Techniques or strategies used during training that assist the trainees in mastering the learning objectives (including lecture, demonstration, discussion, oral questioning, role playing, walk-through, and self-pacing).

Training Plan

A plan that describes course management organization, course loading and scheduling requirements, trainee management and evaluation guidelines, instructor qualifications and responsibilities, course facility and equipment requirements, test administration guidelines, training record requirements, and course curriculum outline.

Training Setting

The environment in which training is conducted and learning occurs. Training settings include classroom, laboratory and workshop, formal OJT, simulator, and self-study.

Validity

The capability of an instrument or process to yield accurate results.

Walk-through

A training method that facilitates trainee transition from learning in a simulated environment to application in the actual job environment; includes plant visits that emphasize physical layouts and observation of trained employees performing their jobs.

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