THAI - CANADIAN
NUCLEAR HUMAN RESOURCES DEVELOPMENT
TRAINING PROGRAM

EFFECTIVE TECHNIQUES IN OPERATION OF NUCLEAR POWER PLANTS

LECTURE NOTES FOR THE COURSE ON

PEER EVALUATION TECHNIQUES

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OPERATIONS

1.0 OBJECTIVE OF PRESENTATION

Ways in which operational activities are conducted to ensure safe and reliable plant operation are discussed. These include ensuring responsiveness to changing plant conditions, clearly identifying limits of responsibility, and ensuring a professional environment in the control room. The importance of accurate clear procedures for both operating and testing are emphasized. The need to have a clear policy on the use of these procedures is discussed. The importance of creating and sustaining an environment in which operators can effectively carry out their assignments is included. OSART results are discussed in the operations area.

2.0 GENERAL

The operation of a nuclear power plant concerns the manipulation of the plant systems and equipment to safely and economically produce reliable electrical power from nuclear energy. This must be carried out with high levels of competence and integrity to ensure that the advantages of this form of energy production are realized whilst ensuring that the risks are minimized.

Management of operation consists of establishing a management system which ensures that the broad range of activities which are necessary to achieve these objectives are effectively carried out on a continuous basis. This includes a process which ensures that the work of other support groups, such as technical support or contractors, for example, conforms to the standards necessary for excellence in operation.

An important element of operations management is to constantly 'walk the talk'. This means that frequent presence in the field is necessary to demonstrate the desired standard, to correct sub standard performance in a supportive way and to determine the underlying causes of sub standard performance.

It is believed that most people want to do a good job. This translates into doing what they believe the boss wants. Therefore it is necessary to clarify what is required and then continuously reinforce it. The lowest standard demonstrated by the operations management organization is the highest standard which can be expected from operations personnel. For example, if the operations manager does not follow industrial safety requirements, or radiation safety requirements, then he cannot expect that his employees will follow them.

This lecture will discuss the following items:

- operations organization and administration
- shift routines and operating practices
- control room activities
- training
- control of equipment and system status
- record keeping and event reporting
- operating and testing procedures
- operator aids
- equipment labeling
- fitness for duty
- use of probabilistic safety analysis
- safety culture
- defense in depth

3.0 OPERATIONS ORGANIZATION AND ADMINISTRATION

3.1 Setting and achieving goals

A comprehensive way of achieving the objectives of the plant and the related objectives of each department is to establish a system of goals and objectives. Ideally these goals should support a long term strategy which sets the future direction of the plant. In addition, an effective way of involving personnel in the recognition of important elements of their job is to set operating goals. These goals are ideally developed with the input of the people who will assist in achieving them, and must include a specific measurable target. An information program must be developed to ensure operations personnel are aware of the goals. They should be displayed where they can be easily seen by plant personnel, and should include a frequently updated indication of performance with respect to the goals. An action plan must be developed and publicized which indicates how the goal can be achieved. This action plan must be adjusted if the goal is not being achieved, or the goal should be changed if it is determined that it is not achievable. These goals should focus on specific areas where improvement is required so that people are not overloaded with information. Differentiation should be made clearly between the general operating philosophy of the department and it's measurable goals.

Typical goals may include:

- number of reactor trips
- operator errors
- capacity factor
- budget
- number of significant personnel injuries
- status of training
- number of lit annunciators in the control room
- number of temporary operating instructions
- number of jumpers.

Operations management must create an environment which permits the achievement of these goals, and must then hold operations personnel accountable to meet them.

One method of achieving this is to have each team prepare a work program for the year, which encompasses these goals, as they apply to their specific function. These work programs must then be periodically reviewed and corrective action taken, if required. In addition these goals and work programs must be reviewed periodically and updated as new challenges present themselves. Operations management must take an active and continuous interest in this programme for it to work. An important element of the use of goals is to remember that goals are a tool to assist with good management and not an end in themselves. Many things are necessary to achieve good management and they will not all be expressed as measurable goals in a specific year. Only those items requiring special emphasis should be included. They may require special emphasis because they are global, or because they address a specific important problem at the plant.

3.2 OPERATING POLICIES

In order to set a framework within which the operating goals can be achieved, it is necessary to set out operating policies. These policies may identify such items as:

- limits of authority of various levels of personnel and supervision
- accountability
- interface with other groups
- requirement to adhere to procedures
- minimum staffing
- overtime
- training requirements
- etc.

4.0 SHIFT ROUTINES AND OPERATING PRACTICES

Professional conduct and good work practices result in appropriate attention to plant conditions. Part of this process is that there must be a clear delineation of responsibility, so that all necessary functions are covered without overlap. Some operations organizations are very complex. This typically means that at the working level there are several different interpretations of the structure which confuse responsibilities, resulting in some things being done twice and others not at all.

It is desirable that administrative tasks for shift operating personnel are minimized, so they can concentrate on their primary responsibility of operating the plant safely.

Effective plant equipment monitoring, both in the control room and in the field, is necessary to detect abnormal conditions or adverse trends, so that appropriate action can be taken before equipment malfunction occurs. Notifying supervision promptly of unusual or unexpected situations aids in ensuring that the appropriate corrective action is taken.

Equipment status and the authority to operate equipment should be understood by all operations personnel, so that activities can be controlled and coordinated and defense in depth can be established and maintained.

Operators must note any deficiencies or safety hazards existing in the plant during their field tours and initiate corrective action to eliminate, control, or contain them. The operators are the primary source of identifying these plant abnormalities and must conduct thorough and comprehensive field tours.

Some plants use operator equipment inspection sheets, which require specific items to be recorded. This can also be a mechanism for trending the change in system parameters before they reach limits, so that the need for corrective action can be predicted. Other plants have a booklet, which is an aid to the operator and prompts his memory. It is important that the operator is alert for abnormalities, which may not have been predicted by round sheets. He must be taught to use his initiative and be alert when conducting field tours, but must recognize the limits of his knowledge and the limits of his authority when changing plant status. He must also ensure that access to equipment is not impeded by maintenance laydown areas or general storage areas and that lighting is sufficient to operate equipment effectively.

Some plants give each crew a special responsibility for an area or unit. This is particularly useful on multi unit plants to ensure good housekeeping and industrial safety standards.

Communications equipment must be provided which enables effective communication within the shift and between support and supervisory personnel in normal and abnormal situations.

5.0 CONTROL ROOM ACTIVITIES

An important aspect of control room activities is that operations management must establish an environment where the control room operator can conduct himself in a professional manner. For example, it is unrealistic to require that the operator must be aware of the reasons for all lit annunciators, if there is routinely a large number illuminated due to poor maintenance practices. Similarly the operator cannot be expected to be familiar with all temporary operating instructions, if there are large numbers of them continuously being issued.

The operator must be attentive at the panels and must frequently carry out inspections of the status of the displayed parameters. He must be responsive to alarms and must not be significantly distracted from this primary role by other activities, or by inappropriate activities in the control room.

There must be a clear understanding of the limits of responsibility of control room operators so that the principle of defense in depth is sustained

In Canada, all changes in reactor power must be approved by the shift supervisor, except in the case of emergency shut down.

The reactivity controls do not permit power to be increased by more than 10% full power at any one time.

The control room operator is constrained to follow operating procedures. Any operation which is not covered by these procedures requires approval of the shift supervisor. He may also need to get higher level approval from the plant manager. For example, resetting a reactor trip requires plant manager approval.

To help establish the best control room environment, access should be restricted to those who have a work related need to be there. In particular, access to the control panels must be by approval of the control room supervisor.

The control room team must establish good communication habits both between themselves and with field operators and maintainers. Many undesirable incidents have occurred due to poor communications. For example, as a consequence of poor communication between a control room operator and a transmission system operator, an incorrect breaker was opened resulting in a load rejection. Another example would be that during a simulator practice of a plant transient there was incorrect communication as to whether a steam generator level was going up or down. This resulted in the wrong incident being diagnosed and the wrong emergency procedure being followed.

It is desirable that all communication of critical information between operators or between operators and maintainers, involves repeating of the information by the individual receiving it, to ensure that the information was correctly received.

If staff numbers permit it, it is desirable that the control room staff routinely visit their unit in the field, so they have first hand knowledge of conditions which exist there.

6.0 TRAINING AND QUALIFICATION

Training is an important part of the operator's job. A control room or field operator is required to respond to a plant abnormality which he/she has not experienced before. Responding to a load rejection, or even participating in a routine start up, for example, may only happen to an operator several years after his initial training. Therefore continuing training is highly desirable, so that operators can practise these rarely used skills on a regular basis.

In Canada, control room operators are required to re-qualify on the full scope plant simulator every two years. The senior operations manager participates actively in the requalification process and ultimately decides if an operator or shift superintendent should retain his authorization. Practice on the simulator occurs throughout the year.

The development of continuing training for other staff categories is in progress.

The detailed training programs for operators are not discussed here due to the broad scope of this lecture.

7.0 THE CONTROL OF SYSTEM AND EQUIPMENT STATUS

It is important that the plant configuration is maintained in accordance with the design requirements at all times. This ensures that the plant is in a configuration which has been **analysed** to be safe. Other configurations may be equally safe, but they have not been **analysed** as safe. This is an important distinction which operating staff must understand.

Maintaining control of system and equipment status is fundamental to good operating practice.

Many operations activities impact on the configuration of the plant They include:

- authorization of status changes
- equipment and system alignments
- deficiency identification
- alarm status
- post maintenance testing
- independent verification

Each of these items will now be reviewed in more depth.

7.1 The authorization of status changes

The senior operating person on shift is generally responsible for maintaining proper plant configuration and should authorize status changes to major equipment and systems. This individual is typically the shift supervisor. He must ensure that this information is passed to the senior control room operator, who would typically supervise the operations required. However, shift supervisors have been observed changing the status of major systems themselves, without communication with the control room staff. This is undesirable, since the control room staff may not know the status of equipment and this may lead to operating errors.

The defense in depth philosophy requires that more than one person should be involved in critical decisions. Therefore each individual on the shift team must know his limits of authority. For example, in Canada the plant manager must authorize a return to high power following a trip.

7.2 System and equipment configuration

Individual components for plant equipment and systems should be checked to ensure that their configuration conforms to the design intent prior to first placing the equipment in service. Alignment check sheets are a useful tool to ensure that this is done correctly.

Subsequent complete configuration checks may not be necessary. Partial checks of specific systems will be necessary, if the configuration may have been disturbed, due to maintenance, for example. More extensive checks may be required following a major outage.

Locks are used to guarantee the status of critical equipment. They are required by law on some components in Canada, such as isolating valves on safety valves. The number of locks should be minimized, due to the difficulty in operating locked equipment in an emergency. Locked components should be listed on a check sheet and periodically checked. Individual components have been found to be locked in the incorrect position in the past.

Tagouts are a common way in which abnormal configurations are created. The shift supervisor must approve tagouts to ensure that the design intent is not violated. Tagouts must be rigorously controlled because both personnel and plant safety can be affected by a poorly administered system.

Temporary changes also have the potential to impact on the control of plant configuration. Unapproved changes or those which are not correctly recorded on control room drawings and documents are of particuiar concern.

Outages often result in abnormal plant configurations which can cause loss of configuration control.

7.3 Deficiency identification

Deficiency identification is a part of the control of system and equipment status. If a component is unavailable because it has an unidentified deficiency, then there is a loss of control of equipment status.

Rigorous identification of deficiencies relies on the effectiveness of field operators. It is also important to label deficiencies, so operators do not unnecessarily identify the same deficiency more than once. This has led to a forced outage due to misinformation on one of two deficiencies on the same piece of equipment.

7.4 Alarm status

Good operating practice requires that the control room operator is aware of all alarms which are in an abnormal state. The operator must also be aware of the reason why alarms are in that state, so that he knows the status of the plant under his operating control.

In order that he can realistically do this, it is incumbent on the plant management to ensure the following:

- maintenance practices must keep the number of out of service alarms to a minimum. Some plants have no more than five alarms out of service at one time.
- operating practices must limit the number of alarms in the alarm state.
- nuisance alarms must be designed out by engineering support. This is particularly important, because if alarms are constantly coming in, then the operator is distracted from properly monitoring the panels. Operators have missed important alarms, because they canceled an alarm without carefully checking. This was due, in

part, to them being desensitized to alarms, because of the large number coming in. (one every twenty seconds, or so).

- operating documentation must clearly tell the operator the cause of the alarm, and the action to be taken as a consequence of it.

7.5 Post maintenance testing

When maintenance is completed it is important to test the equipment for the following reasons:

- maintenance personnel will wish to ensure that the maintenance has been effective
- operations personnel need to ensure that the design intent is still met.

It is often the case during outages that the testing cannot be completed immediately following the maintenance. Planning processes must ensure that post maintenance testing is completed at the earliest opportunity, before the equipment is returned to service.

7.6 Independent verification

Independent verification is part of the defense in depth philosophy.

It is used when critical operation or maintenance is being carried out. In this case, a mistake by one individual could disturb the plant configuration in a way that will have an unacceptable, immediate consequence to plant safety or reliability.

It is frequently a 'no cost' item, since two individuals will often be assigned to one job.

They have to be trained to **independently verify** prior to the work starting, and at critical stages during the work, that the following is true

- they are on the correct unit
- they are on the correct system
- they are on the correct component
- they have the correct isolation
- they are following the correct procedures

Many plant upsets could be avoided by effective independent verification. The chances of two well trained, competent individuals making the same mistake at the same time are remote, but it has happened.

Self checking is also a useful and effective technique to reduce human error. An example of one of several techniques to encourage self checking is to get all staff to do their work using techniques similar to those used by experienced control room operators. They always STOP, then THINK, then ACT, then REVIEW, because they have learned that one control room error can have immediate undesirable consequences.

8.0 RECORD KEEPING AND EVENT REPORTING

8.1 Shift logs

The operating department's records should contain a narrative log of the plant's status and of all events, as required, to provide an accurate history of plant operations. However the number of logs and their function must be properly controlled, so that plant status can be determined without the need to review many log books.

Operating logs are the main means of record keeping on shift. They are typically a narrative sequence of events or functions performed at a specific shift position.

It is important that logs are written up as events occur, so that the correct sequence of events is captured.

Logs typically contain the following types of information:

- reactor mode or condition changes
- abnormal plant configurations
- status changes to major plant systems
- occurrence of reportable events
- testing status
- out of specification chemistry
- completion of operator plant checks
- shift turnover
- etc.

8.2 Shift turnover

Logs also form the basis of the turnover from one shift to another. The turnover should be formalized, so that the outgoing crew must satisfy the incoming crew with respect to the status of the plant before turnover is accepted. It is desirable that a written turnover is provided in addition to a verbal description of status. The written turnover should be in the form of a check sheet to ensure that critical areas are discussed such as:

- regulating system status
- safety system status
- major process system status
- tests in progress or planned
- major maintenance planned
- new operating instructions
- etc..

8.3 Event reporting

Immediate reports must be prepared by the shift crew if an event occurs which the plant has determined to be a reportable event. These event reports may be required by regulatory bodies, for example a reactor scram, or they may be internally required by the plant, for example, a significant personnel accident. They should be prepared on the shift on which the incident occurred, while the facts are still fresh. Since they are immediate reports, they should not attempt a definitive explanation of why an event occurred, unless it is self evident. They should concentrate on identifying what happened and the sequence of events that happened.

9.0 OPERATING AND TESTING PROCEDURES

The policy on the use of test and operating procedures must be clearly spelled out by operations management.

Studies have shown that procedures are a key factor effecting operator performance. The probability of error increases greatly with the use of poorly written procedures. In addition, deficient procedures and the failure to follow procedures are major contributors to many significant operating events.

Procedures which are important to operational safety include:

- operating limits and conditions
- normal operating procedures
- emergency operating procedures
- surveillance and testing procedures
- tagout procedures
- field inspection procedures
- emergency management procedures

The requirement in Canada is that these procedures must be complied with. If it is not possible to follow a procedure, due to plant conditions, or an inadequate procedure, then the work must stop until a new procedure is available. This procedure may be prepared on shift, or it may require technical input depending on the nature of the problem preventing it's use. Without the rigorous compliance with procedures, it is difficult to ensure compliance with the desired plant configuration.

If testing procedures are not complied with, then the test may be invalidated. For example, if an operator taps a pressure switch because it did not pick up at the correct pressure, or if an operator decides to modify a test because it is not working, then the test may be invalidated.

In order for this process to work, tests and operating procedures must be accurate and promptly updated,when defects are identified.

The ideal situation might be described as 'operators intelligently complying with well written, accurate, current, verified procedures which take human factors into account and are available in a controlled manner at the locations where they are required.'

10.0 OPERATOR AIDS

Operator aids can provide useful information to operators in the performance of their jobs. They may be in the form of flowsheets or drawings or procedures or parts of procedures. For example, it may be appropriate to post a generator emergency degassing procedure at the field location, where it may be required quickly. This encourages the use of procedures.

It is important that these procedures are controlled to ensure that they are correct and current. It is not uncommon to find unapproved hand written operator aids in the far reaches of some plants, which may be years out of date and potentially hazardous. Routine checks of the plant are necessary to ensure that only approved operator aids are in use.

It should be remembered that if an aid has been posted, it is probably needed. The appropriate action might be to provide a replacement approved aid, rather than just removing the unapproved aid.

11.0 EQUIPMENT LABELING

Inadequate equipment labeling has also been a contributor to many industry events. It is difficult to be sure that the correct equipment is being operated if it is not clearly labeled.

Even if the plant was correctly labeled when it was first commissioned, labels tend to fall off or become damaged over time. An ongoing program is needed to identify missing labels and replace them.

A recommended process which helps minimize the consequences of incomplete labeling is to have a policy that unlabeled equipment will not be operated until it has been independently identified as the correct piece of equipment and approved by a supervisor.

The quality group should periodically conduct independent checks of equipment labeling.

12.0 FITNESS FOR DUTY

This issue is more significant in some countries than others. It takes different forms dependent upon the culture of the utility or country. The major issues are drugs and alcohol, but may also encompass alertness and mental state. Some countries require random testing for drugs and alcohol at any time. Others rely on supervisory vigilance to recognize abnormal behavior. Others claim there is no problem and have no programme. Some countries allow alcohol consumption in cafeterias or in limited quantities in the control room area. In some countries key plant personnel are required not to turn over responsibility for the plant unless the oncoming individual is capable of doing his job. It is desirable that each manager has considered the situation in his environment and has instituted an appropriate programme, which is periodically reviewed as circumstances change. This review should include an in depth study of the impact of a specific shift schedule and overtime rules on the performance of operators.

13.0 PROBABILISTIC SAFETY ANALYSIS (PSA)

PSA is a methodology which was originally developed to identify and understand key plant vulnerabilities to core damage. It's use is now expanding into a living PSA which has the capability to enhance plant operations in ways which can be most effective from a safety and economy point of view. For example it has been used to:

- enhance operator training
- prioritize modifications
- establish allowed outage times for safety related equipment
- improve emergency operating procedures
- study vulnerabilities during outages.

14.0 SAFETY CULTURE

The International Safety Advisory Group (INSAG) defines safety culture as:

Safety culture is that assembly of characteristics and attitudes in organizations and individuals which establishes that, as an overriding priority, nuclear plant safety issues receive the attention warranted by their significance.

Culture is a matter of attitudes and behaviors, both of individuals and the organization at each structural level. Attitudes are difficult to influence directly, but should change with time when the benefits of improved behaviors become apparent. Behaviors are more directly influenced by the systems and procedures within which people work.

Some desirable elements are:

- realistic, achievable, well publicized goals and objectives in the area of nuclear safety, which are developed with staff participation
- action plans to achieve them
- simple easily understood indications of success, or the need for additional effort
- reinforcement of desired behavior by managers in the field
- creation of an environment where staff feel ownership for the safety performance of the plant

15.0 DEFENSE IN DEPTH

Defense in depth consists of a hierarchical deployment of different levels of equipment and procedures in order to maintain the effectiveness of the physical barriers placed between radioactive materials and workers, the public or the environment. Defense in depth must be effective in normal operation, anticipated operational occurrences and, for some barriers, in accidents at the plant.

The objectives are:

- to compensate for potential human and equipment failures
- to maintain the effectiveness of the barriers
- to protect the public from harm even if the barriers are not fully effective.

The strategy for achieving defense in depth is twofold: first to prevent accidents and, second, if prevention fails, to limit their consequences.

Defense in depth is generally structured in five levels. They are:

- prevention of abnormal operation and system failures
- control of abnormal operation and system failures
- activation of specific safety systems and other safety features
- limitation of accident progression through accident management
- mitigation of the radiological consequences of significant external releases.

Effective implementation requires conservatism quality assurance and safety culture. Important operational requirements are:

- infrequent deviations from normal operation
- surveillance and in service inspection
- good material condition

- procedural compliance
- training
- safety culture
- human factors.

One might characterize the main nuclear safety objective of nuclear operations as ensuring that all system, equipment and people aspects of defense in depth are correctly carried out.

16.0 OSART EXPERIENCE

Operation of a nuclear power plant is a core activity and hence operators are generally well qualified and often well trained but there is still room for improvement.

Insufficient retraining and refreshment of knowledge are frequently noted. Most operators have access to a full-scale, but not always full-scope, simulator. Sites which are not equipped with such simulators often have multi-functional simulators.

Many of the plants visited have symptom-based emergency operating procedures (EOPs). However, development of symptom-based EOPs for former-Soviet designed plants, which was started in 1992, is still not completed.

Although significant progress has been observed in this area, it is noted that operators are not always complying with, or not using, procedures. This is not always corrected by managers and supervisors when they are in the field, because they do not always recognize, as an internationally accepted philosophy, that the highest level of safety is ensured by having highly trained and qualified operators consistently using and following well structured and written procedures.

A more difficult issue to resolve is the configuration control of the installation to ensure that the unit is at all times in the status that operators believe it to be. Difficulties are noted in areas such as equipment labelling, operational documentation control, alignment procedures, checking, work authorization process, temporary modification control and shift turn-over. Several recommendations and suggestions were made in these areas. This area needs the permanent attention of everybody.