COMPETENCY ASSESSMENT OF REACTOR OPERATOR CANDIDATES USING FULL-SCOPE SIMULATORS
THE EMERGING CANADIAN REGULATORY APPROACH

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1. INTRODUCTION

The Atomic Energy Control Board (AECB) is the Canadian agency responsible for regulating the development and operation of nuclear facilities in the country. The mission of the Operator Certification Division (OCD) of the AECB is to obtain and document assurance that key nuclear generating station (NGS) operating personnel are initially well trained and adequately competent to perform their duties and that, through periodic retraining and re-qualification activities, their competence is maintained. Assurance through direct scrutiny by the regulatory body that operating personnel are competent is obtained now for just two groups of on-site NGS staff: Shift Supervisors (SSs) and Control Room Operators (CROs). The present arrangement requires SS and CRO candidates to pass five separate written examinations (Radiation Protection; Conventional and Nuclear General; Conventional and Nuclear Specific) which are set and graded by OCD staff. From time to time and for special reasons, it has been deemed necessary to gauge competence by evaluating candidates on full-scope plant simulators. However, there is presently no routine regulatory testing using simulators.

Since full-scope plant specific simulators are now available at each of the seven CANDU plants (22 reactors) in Canada, the regulatory intention is to develop routine simulator testing of SS and CRO candidates and to introduce it as a distinct and separate element of the certification process. Assessment of a candidate's knowledge of plant behaviour and of the actions to be taken under upset conditions can be carried out more effectively using a simulator than during a written examination. This is evidently due to the high degree of realism that a simulator brings to the testing environment in terms of performance of the actions required, time-stress element and possibility of confronting CRO and SS candidates with unexpected events. This paper describes the work done and the experience gained so far by the OCD in developing a suitable full-scope simulator examination method for assessing the competency of CANDU CRO and SS candidates.

2. SCOPE OF THE SIMULATOR-BASED TESTING METHOD

A review of the existing literature on the use of full-scope simulators in the nuclear industry for certification purposes shows that there has been little systematic study on the subject. However, considerable agreement can be found in the available literature regarding the significant difficulties that assessment of control room staff using this tool presents. Although simulators have been used for many years in the nuclear industry for CRO and SS training, there is still no wide-spread standard practice or methodology for simulator-based assessments.

The approach to testing presently under consideration at the AECB applies mainly to CRO candidates. A different approach will have to be developed for SS candidates and particularly for those in multi-unit Canadian NGSs, due to the very different nature of their job. Before becoming authorized, CRO and SS candidates will have to pass a final AECB examination on their plant-specific full-scope simulator to demonstrate their competence. In our approach, two OCD examiners assess the performance of a single CRO or SS candidate working within a team whose composition is intended to be similar to that normally available for operation in the main control room at the candidate's NGS so as to ensure that candidates have adequate support as they would have during a real occurrence. This first requires a clear definition of the composition of the support team and of the responsibilities of each of its individual members. We have observed that until very recently the responsibilities of individual team members in the control room of CANDU NGSs not only were not clearly defined and documented, but they even varied somewhat from crew to crew at the same NGS. A clearly documented definition of team composition and of the roles and responsibilities of individual team members is essential to ensure proper team response during real incidents or accidents. It is also a prerequisite to obtain a valid and reliable assessment of the competence of individual CRO or SS candidates. In defining team composition, and members' roles and responsibilities, particular attention should be paid to ensuring that, in the event of any foreseeable severe plant upset, demands on the team members including the CRO and the SS, are manageable and not excessive.

For initial certification examinations, it is presently our intent to use an operating team corresponding in size and composition to the minimum team that the station has committed itself to maintain on shift at all times. Moreover, some of the team members could be made unavailable for some time, at the start of a test scenario, as it might indeed happen during a real incident at the station. For multi-unit stations, some team members, like the CROs of adjacent units, could even be made unavailable for the whole duration of a test scenario to reproduce the conditions that would exist during an incident involving several units.

During the test of a given CRO or SS candidate, the other team members who are made available by the responsible utility training centre, act in accordance with precise guidelines established beforehand by the OCD examiners. This is to minimize the impact on the test results of an unexpected behaviour of team members. For examination purposes, it may be necessary to limit the actions of these team members. For example, when examining a CRO candidate, the person playing the role of the SS will not be allowed to give to the candidate information that a CRO is expected to know. The actions and communications performed or exchanged by the members of the support team during a particular test scenario are specified in advance in appropriate test procedures to avoid the possibility that the CRO or SS candidate might benefit from excessive support or suffer as a result of unplanned errors by teammates.

3. SIMULATOR CHARACTERISTICS REQUIRED

There are presently no regulatory acceptance criteria in Canada for full-scope simulators. Therefore, before regulatory examinations on simulators can be carried out in practice, the OCD and the Canadian utilities are performing a review of the current status of each of the seven plant-specific simulators to ensure that it has the minimum required characteristics to support the proper conduct of such tests. Although they are still under review, the minimum characteristics that we expect the simulators to have are outlined below.

Each simulator must be capable of reproducing with sufficient fidelity the consequences of all the credible safety-significant equipment failures and plant abnormal, transient and accident conditions. Where plant response and operator actions are a function of the severity of the failure or condition (e.g., pipe breaks, loss of inventory, loss of flow, loss of pressure, loss of vacuum,etc.), the simulator must be capable of covering the entire possible range of the condition or failure . According to our observations, the simulators are often too limited in the number of scenarios that they can handle properly. This may be due to insufficient initial simulation specifications or to failure to verify during simulator commissioning the correct response of a large number of simulated equipment malfunctions supplied by the manufacturer. It is important that the simulators be versatile in their capability to simulate correctly combinations of different equipment malfunctions in order to reflect the large number of possible failure sequences that could occur in practice. When the possibilities of equipment failures for any given system are too limited, the CRO and SS trainees are usually able to identify rapidly the simulator limitations in this area. It becomes impossible then to test candidates in a realistic manner on their ability to diagnose and to handle abnormal system conditions as the situations presented to them are not truly representative of the diversity of possible malfunctions at the real plant. A preliminary list of equipment failures and of abnormal, transient and emergency conditions, which can be addressed from the Main Control Room, that each simulator must be capable of reproducing realistically and in real time has been issued for information by the OCD. This list will be used by the utilities to assess the status of their simulators.

The simulators used for certification examinations must be very reliable. Simulator failure or faulty operation during an examination does, in general, invalidate the result of the test scenario in progress and possibly invalidates the whole examination. Since the preparation of simulator examinations is very time consuming, such occurrences must clearly be minimized. They should also be minimized to be fair to the CRO and SS candidates. The criteria and a method for assessing the reliability of simulator operation are presently being developed by a Standing Inter-Utility/Regulatory Working Group working through an ad hoc Subgroup on simulator-based testing.

The simulator must be equipped with complete automatic data collection devices to obtain a reliable, objective and complete record of operator performance. These devices should include a trainee action monitor (TAM) that keeps a complete record of all the actions performed by any individual on the simulator panels with the time when each action occurred. Without the TAM, it is virtually impossible to obtain a complete record of operator actions because of their number and the speed with which they are taken during certain phases of the test scenarios. Certainly, accurate timing of the actions cannot be obtained without the TAM.

The simulator should also be equipped with a good quality audio and video system to record the performance of the CRO or SS candidate and the other team members during the test. Our experience with tests conducted with consultants at a Canadian simulator is that such data are particularly important to determine the impact of the communications taking place on the actions performed and to identify who in the operating crew has performed a particular action recorded by the TAM. It is also of great help when assessing candidate behaviour since, at times, the speed at which operators are asking for information, acknowledging messages from their colleagues and performing actions is very high. These recordings also provide indication of delays in implementing procedures which may show a lack of understanding on the part of the CRO or SS candidate or inherent ambiguities in the procedures. A time reference signal should be recorded on the video tape and it should be correlated to the time signals used by the computer driving the simulator so that the various test records can be compared readily for performance assessment.

The simulator computer should also be able to collect, store and recover on demand a complete historical data record of the plant parameters selected for each test scenario as well as a complete record of all alarms received in the simulator control room. This information is important to assess the performance of the CRO or SS candidate in maintaining or returning key plant parameters within an acceptable range. It must be possible to label the values of the parameters with the time when they were sampled to allow these data to be correlated with those from the other recording devices. Ideally, time signals should be fed from the computer to the other recording devices so that time correlation is possible. It is very important to ensure that the data logging capabilities of the simulator computer are totally independent of its operation as a simulator and that these two kinds of functions do not interfere with one another.

4. SELECTION AND DEVELOPMENT OF TEST SCENARIOS

Test scenarios are selected to verify the capability of a CRO or SS candidate to diagnose and to deal correctly with significant plant upsets and equipment malfunctions. A special effort should be made to present the candidate with credible scenarios that are not an exact replica of those seen during training. Although basic test scenarios usually represent situations that are covered by operating procedures for abnormal or emergency conditions, variations are introduced to present the candidate with situations that are not addressed directly in the operating procedures. We believe that test scenarios should challenge CRO and SS candidates beyond the need to follow a strict path through operating procedures. One objective is to measure the problem-solving ability of the candidate when faced with situations for which procedures give no clear instructions or for which no procedure exists. The candidate is then expected to use the knowledge and operating skills acquired during training to determine the correct course of action. These variations in scenarios can be arranged by changing the sequence and the rate of occurrence of events that require the use of one or more specific operating procedures.

The most important way to introduce variations in a basic test scenario, as, for example, in a loss of coolant accident in the reactor coolant system, is to use credible additional malfunctions of equipment that could occur during such an accident and that would force the CRO to modify the course of action prescribed by the procedures. We consider that it is of the utmost importance that any specific test scenario including its initial conditions, primary failure and additional malfunctions be legitimate and well-founded. Therefore, the additional malfunctions introduced must be relevant to the incident taking place. For example, additional malfunctions may be dormant faults in standby equipment that manifest themselves only when this equipment is called upon to act. Other relevant equipment failures that might happen during normal plant operation should be used as additional malfunctions, even if they would have a low probability of occurrence during the limited duration of the test scenario. In fact, operating experience has shown that sequences of failures considered very improbable have occurred on many occasions. Preferably, additional malfunctions of equipment are chosen that have a significant impact on the major plant parameters so as to determine whether the CRO or SS candidate can perform proper monitoring of the parameters and effective handling of the malfunctions. However, the number and timing of failures in any particular test scenario should be such that a competent candidate will not normally have undue difficulty in handling the situation adequately.

The scenarios developed must also be compatible with simulator design. In our approach to simulator testing, a scenario will not be used if in running it, we find that the simulator does not behave like the real plant, even if it would be desirable to test the ability of the candidates to handle that particular situation. It is also very important that the initial conditions, the additional malfunctions of equipment with their respective time of occurrence and the end point of the scenario be very clearly defined. The plant parameters that will be recorded during the event to monitor the state of the plant and the effectiveness of the candidate in handling the situation also have to be selected in advance.

One must then develop the assessment guide that will be used by the examiners to evaluate the performance of the CRO or SS candidates during the scenario. This assessment guide is a checklist that provides the detailed sequence of actions, checks and instructions to other team members in the control room and in the field expected from a CRO or SS candidate during the test scenario. The checklist is prepared using the operating procedures that should be used by the candidate to respond to the situation. However, it also includes all other actions, checks and communications expected from the candidate, but that are not specifically mentioned in the operating procedures such as actions considered as operator skills and the monitoring of major plant parameters. It also includes any action expected of the candidate when facing situations not specifically addressed by the procedures.

Moreover, when selecting initial conditions or additional malfunctions that introduce situations not directly addressed in the operating procedures, it is important to look for cases for which the required course of action is clear. The preparation of the assessment guide may lead to modifications of the test scenario to avoid cases where the expected course of action cannot be established with confidence.

The test scenarios for a given examination are selected by the OCD examiners but they are developed and finalized with the participation of operating experts from the station. Their participation is considered important to ensure that each test scenario is technically correct, with the simulator behaving like the real plant, and that the expected candidate response is in accordance with station operating practices and performance expectations.

Once the test scenarios for a given examination have been developed, it is necessary to confirm the correct response of the simulator and the adequacy of the expected candidate response for each scenario. This confirmation is obtained by administering the examination to either a CRO, a SS or a simulator instructor who has not been involved in its preparation. This exercise is also used to estimate the length of time required to complete each scenario. Due to their great familiarity with the content of the test, examiners tend to underestimate significantly the time required for a CRO or SS candidate to handle a particular situation. It is important to obtain good estimates of the time required to administer each test scenario to avoid submitting candidates to excessively long examinations. Rehearsals of the test scenarios with the operating support team are also made before giving the test to the candidate to ensure that each team member will act in accordance with the test guidelines.

5. PERFORMANCE MEASUREMENT AND ASSESSMENT CRITERIA

The main performance measure used for assessment is the detailed record of actions, checks and communications made by the CRO or SS candidate. These are primarily recorded by the OCD examiners on the assessment guide checklist. This record is backed up by the TAM record and by the audio and video recordings. These are used to clear up any ambiguity that may exist in the observations made by the examiners during the test and contribute to making the assessment process as objective as possible. However, it is very difficult to obtain a reliable record of the monitoring of plant indications and parameters performed by an individual since this activity is often not evident. The detection by the candidate of additional malfunctions is one obvious way that shows clearly that adequate monitoring was performed. However, considering the very limited number of additional malfunctions planned for any given test scenario as compared to the very large number of checks required to monitor safe unit operation, this method alone is not sufficient. Consequently, we believe that the candidates should verbalize all the checks made during the examination. To obtain a complete understanding of candidate performance, we also intend to ask supplementary questions at the end of each scenario. This is particularly important when the candidate deviates from the course of action expected.

Another important kind of performance measure is the automatic record of the plant parameters that is collected during a test scenario. This record is used to assess the quality of candidate performance and, if necessary, to analyze any unexpected behaviour. Our long term goal in this area is to establish at what point major plant parameters would reach undesirable and unacceptable values during a scenario. This would help in identifying inadequate candidate performance more easily and objectively.

A detailed discussion of the assessment criteria we plan to use in simulator-based examinations is beyond the scope of this paper. Additional information on the subject may be found in an AECB research report on full-scope simulator testing methods[1] prepared by a consulting firm that will be published in the near future. In short, to assess the candidate performance, the OCD examiners analyze all deviations, omissions and errors made by the candidate as compared to the expected response in the assessment guide. The result is a subjective expert judgment based on the candidate's shortcomings considering their actual and potential consequences on plant operation and safety. The quality of the communications made by the candidate and the candidate effectiveness in directing the team of operators are also taken into consideration, but so far, these two factors have played a relatively minor role in the overall assessment process due to a lack of clearly defined assessment criteria for judging communications and team work. A set of generic expectations for CRO and SS that could become the basis for establishing a comprehensive set of assessment criteria has been developed by the Subgroup already mentioned.

We hope eventually to be able to quantify the test result for each scenario by assigning numerical values to all deviations, omissions and errors with weighing factors based on their severity. However, for this to be achieved, extensive work in consultation with the utilities will be required.

Further work is still required for developing a method for assessing SS candidates and particularly those of multi-unit stations. At these stations, the SSs do not operate reactor controls. In the event of an upset, they are primarily responsible for monitoring major plant parameters and alarms to ensure that the station remains in a safe state, for diagnosing independently the nature of the upset and associated plant malfunctions, and for verifying that adequate actions are being taken by the operators. In fact, their performance is essentially passive as long as the station remains in a safe state and plant systems and operating personnel are responding correctly. To make a proper assessment of such SS candidates, scenarios will have to be designed carefully to force the SS to intervene frequently enough to obtain a sufficient basis for a sound assessment of competence. For example the need for such an intervention may be created by having a CRO in the team committing a planned error of diagnosis leading to the selection of an inadequate operating procedure, or a planned error during the execution of an appropriate procedure. As discussed previously, this may also be achieved by presenting the candidate with situations not addressed specifically in the operating procedures. In all such cases, the SS candidate would be expected to determine the correct course of action.

6. RELIABILITY AND VALIDITY OF THE ASSESSMENT

It is extremely important to ensure that the assessment method is reliable and valid. Reliability is that property which ensures that the result or the score obtained by any given candidate on a particular test is consistent from one team of examiners to another and remains so if the test is given at different times. For example, tests of reliability should be conducted to demonstrate that different teams of examiners working independently would assign very similar scores when assessing the performance of a CRO or SS candidate on a particular simulator examination. If the reliability of the method is not assessed, a significant part of the score obtained by candidates may be due to chance and the magnitude of this part will remain unknown. To establish the degree of reliability of the method, an extensive number of tests will be required to obtain a reliability coefficient value that is statistically meaningful. This may be difficult and may take a number of years due to the relatively small population of CROs and SSs in Canada.

Validity is the degree with which the assessment method will rate competent CRO and SS candidates as suitable for certification and reject those who are not sufficiently competent. If the validity of the method is not demonstrated, it is not completely clear what the method is measuring. To determine validity of the assessment method, we need a criterion that is not part of the method and against which the method must be measured. One problem in establishing method validity is that there is no objective way of telling which of the CROs and SSs currently authorized are very good and which are relatively poor. Moreover, the fact that CANDU reactors are highly automated further complicates the matter since the automatic response of systems may mask to a significant extent a lack of competence of CROs and SSs. The quality of CROs and SSs participating in validation tests will have to be ranked by expert judgments made on the basis of their past operating and training history. These judgments should be based on inputs from regulatory staff and staff from the nuclear industry including managers, supervisors and other CROs and SSs. Validation tests will have to be conducted by administering simulator examinations to individuals who have not been involved in the development of the method and ranking in competence from highly competent CROs and SSs with several years of experience to CRO and SS candidates at different stages of their training. An assessment method can be considered as valid if the validity tests demonstrate a high correlation between the scores obtained by authorized individuals and trainees using this method on one hand and the ranking of competence established on the basis of expert judgments prior to the validation exercises on the other.

Finally, it is important to point out that an assessment method which has been demonstrated to be reliable and valid can still yield unsatisfactory results if used in an inappropriate manner. Members of the assessment teams must be trained to use the method exactly as designed. Estimates of the reliability and validity of the examination method only apply as long as it is used exactly as it was during the reliability and validity tests. Each assessment team member must follow a detailed procedure to ensure as far as possible that all the steps of the method are performed correctly and in the right sequence. It is also important that the assessment team members receive refresher training on the use of the method.

7. POSITIVE CONSEQUENCES OF INTRODUCING SIMULATOR-BASED REGULATORY TESTING

We have already noticed two significant positive consequences that have resulted from the work performed so far for introducing simulator-based regulatory testing. Firstly, significant progress has been made at some NGSs in defining the types and number of control room staff, with their respective roles and responsibilities, required to operate a unit under upset and emergency conditions. At these NGSs, because our assessment method focuses on the assessment of a single CRO or SS candidate at a time, roles and responsibilities of CROs and SSs are now better defined and adequate support staff in the control room are now available to make the tasks of CROs and SSs manageable.

Secondly, at most NGSs, the quality and effectiveness of the operating documentation have been improved significantly. Good procedures help prevent the possibility of competent candidates failing the AECB certification examination due to inadequate or erroneous operating procedures. Again the need was recognized by the NGSs to provide their CROs and SSs with supporting documentation that would make their task manageable. Another contributing factor to the improvement of the operating procedures has been the insistence of OCD examiners to include in simulator test scenarios a number of additional equipment malfunctions that are not usually addressed in procedures. The inclusion of such malfunctions in basic test scenarios, otherwise covered by operating procedures for the corresponding abnormal or emergency conditions, has revealed many situations where the operating documentation was not providing sufficient guidance to the CRO or SS for handling the resulting conditions properly.

8. CONCLUSION

We have outlined in this paper the approach to routine simulator-based testing that the AECB is developing for the assessment of competence of CRO and SS candidates. Because of our experience with ad hoc simulator examinations, a subsantial amount of the basic ground work had already been laid. However, some further tasks remain to be completed. The first one is the need to complete the assessment of the status of the simulators already available at the various NGSs to ensure that each of them has the proper characteristics (capabilities, fidelity and flexibility) to support the conduct of such tests. This work is presently under way.

Another task is the development of a database containing a number of test scenarios with associated malfunctions which is truly representative of the diversity of upsets and accident conditions possible in a real plant. The selection and development of suitable scenarios is made more difficult by the necessity of having to measure the problem-solving abilities of CRO and SS candidates when facing situations for which no guidance exists in the available operating procedures. We are presently working closely with the utilities to identify the types of scenarios that are testable and to define the extent and depth of testing.

Finally, another task which is not yet completed is the finalization of suitable criteria for the assessment of candidate performance and behaviour during the tests. Here again we are profiting from our past experience with simulator examinations and from close consultation with utilities. In addition, we are studying closely the recommendations on the subject that are contained in the AECB research report mentioned previously and, in cooperation with the utilities, we will be carrying out validation tests of the criteria selected.

We believe that simulator-based testing of CROs and SSs is a very effective tool for assessing their competence and we are committed to its introduction in our examination system in early 1993. In consultation with the utilities, we have begun detailing the arrangements and the actions necessary to get this testing underway.

We are confident that the incorporation of this activity into our certification process will help better to assure that CROs and SSs are well-trained and competent.

9. REFERENCES

(1) FEHER, M.P., MORAY, N., SENDERS, J.W., BIRON, K., "Evaluation of Full-Scope Simulator Testing Methods", AECB research report to be published.