Minimum Staff Complement: Safety in Numbers

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Abstract

Adequate staffing is an essential safety barrier for event mitigation. For this reason, Canadian nuclear power plant (NPP) licences specify the minimum staff complement (MSC), which is the number and qualifications of staff always required on-site. A systematic analysis and its validation form the basis of the MSC. The analysis and validation demonstrate a licensee is able to control, cool and contain the reactor after any credible event. The CNSC published regulatory guidelines for analyzing the basis for essential staff levels, monitoring compliance with these levels, and controlling MSC changes (G-323). Lessons learned from a full-scale MSC analysis are discussed.

1. Introduction

Nuclear plant workers are essential for ensuring safety at nuclear facilities from normal operations through to emergency response. Adequate staffing is an integral part of a licensee's approach to event mitigation. Operators must be available to assess the state of the plant, confirm that designed automatic safety actions are carried out, and perform required operator actions [1]. Operator actions may be required in the main control room (MCR) or in the plant. In addition, personnel must be available to respond to emergencies, like fires, when necessary. The minimum staff complement (MSC) enables the execution of critical safety functions during normal operations, event mitigation, and emergency response.

2. Regulatory context

The *General Nuclear Safety and Control Regulations* [2] stress the importance of staffing by requiring licensees to "ensure the presence of a sufficient number of qualified workers to carry on the licensed activity safely". One way licensees meet this requirement is defining a MSC, which is the "minimum number of qualified workers who must be present at all times to ensure

the safe operation of the nuclear facility and to ensure adequate emergency response capability" (3). A long-standing position of the CNSC (formerly known as the AECB) is the MSC must be documented and referenced in the operating license [4]. A licensee is only permitted to change the MSC with written approval from the CNSC.

In recognition of the importance of having an evidence-based minimum staff complement, the CNSC published a regulatory guide on the topic; G-323 is entitled *Ensuring the Presence of Sufficient Qualified Staff at Class I Nuclear Facilities – Minimum Staff Complement* [3]. The Guide informs licensees about how they can meet the CNSC's expectations for the baseline analysis, for monitoring compliance, and for controlling changes to the MSC (3). A conceptual framework of the topics addressed in G-323 is shown in Figure 1. Expectations in G-323 are based on earlier reviews of minimum complement staffing by CNSC staff [5, 6]. The publication of G-323 followed the CNSC process for production of regulatory documents and included the opportunity for public consultation.

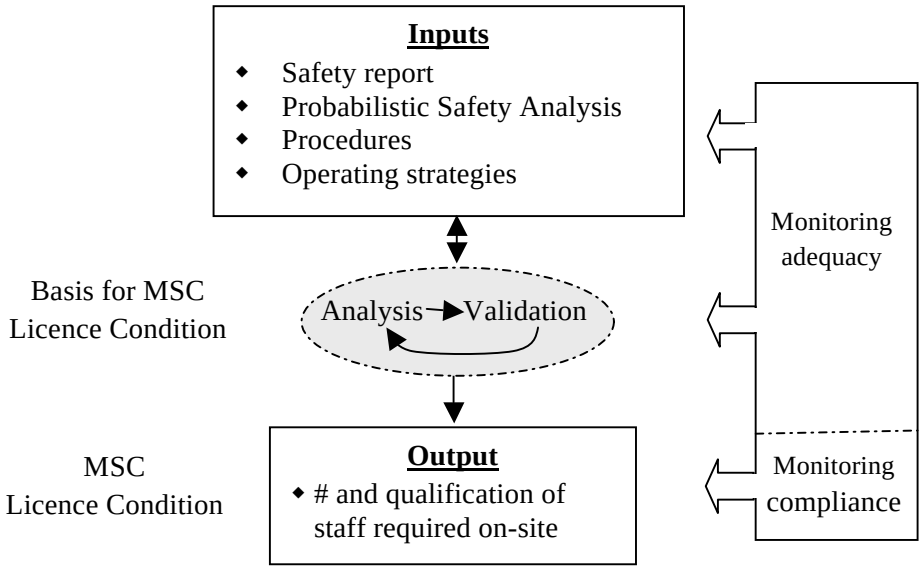

Figure 1: Conceptual framework of MSC assessment process.

3. Determination of minimum staff complement

The basis for the MSC is a systematic analysis to determine the number and qualifications of staff required; the results must then be validated.

3.1 Systematic analysis

A systematic analysis is used to identify the most resource-intensive conditions and to determine the number and qualifications of staff required to respond to events. Actions required for the most resource-intensive conditions under all operating states, design basis accidents, and emergencies must be included in this analysis. This information is derived from operator actions identified in design basis events in the Safety Report and credible events in the Probabilistic Safety Assessment (PSA). Procedures are an important input to the analysis since critical operator actions identified in the Safety Report and PSA are incorporated into a plant's operating procedures and field handouts. In addition to procedures, the operating and emergency response strategies also affect staffing requirements; for example, field operators may always be dispatched in pairs during an emergency. Additional inputs to the analysis include the following: communication strategies, event diagnosis, command and control protocols, concurrent use of procedures, independent verification, facility monitoring, provision of qualified relief workers, restrictions on the location of certain key staff (e.g. shift manager) within the nuclear facility, time constraints, and decision making strategies. All of these factors have the potential to impact MSC staffing requirements and so must be included within the analysis phase of the project.

Several work groups are required to successfully respond to events. In addition to operators, the following work groups are expected to be considered in the MSC analysis: maintainers, emergency responders, chemistry technicians, and stock-keepers.

Depending upon the configuration of the specific nuclear facility, the following issues should be considered within the analysis:

Single unit station*:* The analysis must identify the numbers and qualifications of staff necessary to respond to the event or events which require the most resources in each work group.

Multi-unit station: The analysis must include single unit events (e.g. pump failure), single unit events which can then affect other units (e.g. main steam line break), and common mode events which affect multiple units (e.g. loss of bulk electrical system). The analysis for this type of facility must consider coordination of station resources for response across multiple units and the increased workload for certain positions.

Multi-unit / multi-station: The analysis must include single unit events, single unit events which then affect other units, common mode events which affect multiple units and events which affect multiple stations (e.g. seismic event). In this scenario, the analysis of the specific staffing requirements is more complex and should consider the following: coordination of the emergency response, command and control, and coordination of shared resources between units and stations.

3.2 Validation

Throughout the analysis process to derive the MSC staffing numbers and qualifications, the results must be validated. Validation is the process of determining the degree to which the design of the system facilitates the achievement of the overall safety goals [7]. The safety goals in this case are controlling the reactor, cooling the fuel and ensuring the integrity of containment. Validation exercises demonstrate whether or not the MSC identified by the analysis can successfully respond to the most resource-intensive events. The underlying logic is a MSC which can respond to the most resource-intensive events for each work group is robust and can successfully respond to less resource-intensive events.

Validation should be an iterative process, using methods with progressively higher degrees of fidelity to confirm and refine the information gathered throughout the analysis. For example, a table top validation exercise with Subject Matter Experts (SMEs) may be an appropriate first step to estimate the timing of activities in the field. During a table top exercise, SMEs estimate timing requirements for tasks based on procedures and their knowledge of the plant. This type of validation is typical in the early phases of the systematic analysis. Subsequent field walk-downs and simulation of field activities provides a more accurate evaluation of timing and workload and can identify procedural inadequacies, plant configuration discrepancies, and accessibility issues.

An event that challenges a station's resources is likely to be complex, involving several procedures and the interaction of many different work groups. Early validation activities may be conducted with limited consideration of a worker's entire job. For example, a field operator may walk down a procedure in the field to assess the time required with little interaction with MCR staff; during an event there may be additional pressures on the field operator that interfere with successful task completion. Integrated system validation provides the most accurate estimate of resources required by capturing the complexity of the most resource intensive events.

Integrated system validation is defined as "an evaluation using performance-based tests to determine whether an integrated system design (e.g. hardware, software, and personnel elements) meets performance requirements and acceptably supports safe operation of the plant [8]. The use of specific performance criteria during the validation exercise ensures the licensee can determine if the goals have been achieved. During an integrated validation exercise, issues such as command and control, communication, and workload can be assessed more effectively. An integrated validation exercise demonstrates the adequacy of the MSC in achieving the safety goals of controlling, cooling and containing the reactor during a resource challenging event.

Other modern approaches to validation, such as computerized agent-based simulation of teams or crews, might be useful but remains largely unused in the industry.

3.3 Output

The output of the systematic analysis and validation is an evidence-based minimum staff complement. The MSC numbers and qualifications are documented by the licensee and referenced in the operating licence. Maintenance of the MSC is a license condition and is monitored by both the licensee and CNSC.

It is essential that the methodology and results are documented, so that both licensee and CNSC staff can review them and fully understand the logic of the process followed. The methodology must be documented in enough detail that the work could be replicated by others. The documentation serves as a knowledge management tool, retaining the basis of the MSC for any future work regardless of turnover of licensee or CNSC staff.

4. Monitoring

4.1 Monitoring for compliance with MSC

Licensees must have processes to ensure that the MSC is met at all times. Shift scheduling processes should incorporate factors such as hours of work limits, vacation requests, training requirements, and staff call-in or hold-over provisions. Some licensees utilize additional administrative staffing levels that exceed MSC requirements for staffing MSC positions. The shift scheduling process and administrative staffing levels are barriers against MSC violations due to planned or unplanned absences.

Licensees must monitor the MSC each shift so they do not fall below the required MSC numbers for any particular work group or emergency response role. For some positions, a face-to-face turn-over is conducted at each shift change. A number of licensees have an electronic monitoring system for the MSC. The electronic monitoring system warns MSC staff attempting to badge out at the end of a shift if qualified relief has not yet arrived in the station. Staff from the MSC is expected to stay in the station until qualified relief has arrived. Face-to-face turnover and electronic monitoring systems protect against even short periods of time when MSC is not met.

If a violation of the MSC occurs, it must be reported to the CNSC. The causes of violations should be ascertained by the licensee to inform corrective actions.

4.2 Monitoring the adequacy of MSC

Licensees have many sources of information which can be accessed to identify concerns related to MSC, such as the following.

- Reporting systems that staff uses to raise safety issues may identify concerns about MSC staffing contributing to an event or may highlight weaknesses in the depth of coverage available.
- When events occur, findings from root or apparent cause analyses may identify issues with staffing levels.
- Licensees are required to conduct regular emergency exercises and drills [9]. Both present an opportunity to assess the adequacy of MSC staffing.
- MSC violations may be an indicator that there are insufficient qualified people to fill MSC positions. Other indications related to depth of coverage include violations of hours of work limits by MSC staff or difficulty obtaining relief staff for planned or unplanned absences.

Licensees should have a process for searching their own data for performance indicators related to the MSC. In addition, licensees should have a strategy for learning lessons about minimum staffing levels when events occur within and outside the nuclear industry.

4.3 Control of changes to MSC

Once a baseline analysis and validation are completed and accepted by the CNSC, the evidence-based MSC becomes the foundation for any future changes to the number or qualifications of MSC staff. For example, changes may be required to MSC staffing due to equipment modifications in the plant, procedural changes, or new knowledge gained from the safety analysis, probabilistic risk assessment, or operating experience. Conversely, it is also important to ensure that any proposed changes to the MSC are evaluated with respect to the impact on the achievement of the safety goals and credited operator actions identified in the safety report. Changes to the training qualifications for positions referenced in the MSC must be evaluated to ensure the de-linking of a particular training qualification does not create a situation where MSC staff is no longer qualified to complete actions necessary to mitigate an event. A documented analysis supporting the minimum staff complement provides the licensee and CNSC staff with a foundation for assessing the impact of proposed changes on safety.

To ensure the analysis for MSC does not become out-of-date, the licensee should implement a systematic process for ensuring that changes to the input documentation do not invalidate the MSC. A change management approach for significant changes to the MSC or inputs to the MSC should be utilized to ensure that the basis for the MSC remains valid.

5. G-323 Implementation project: lessons learned

CNSC staff is in the process of assessing the MSC documentation of several licensees against the requirements of G-323. A recent full-scale implementation at one facility identified a number of important lessons learned.

5.1 Systematic analysis

- A multi-disciplinary approach by both the licensee and the CNSC is required to ensure a thorough understanding of event progression and staffing requirements for the resource-limiting event(s). Staff from reactor safety, PSA, operations, emergency response, human factors (HF), and training was used by both the licensee and CNSC during this full-scale implementation project.
- A single unit event may require many tasks by a particular work group, such as control maintenance. This single unit event may be a work group's most resource-intensive event even though it is not the station's most resource-intensive event. The MSC is based on a combination of the staffing requirements for the resource-limiting events for each work group.

5.2 Validation

The validation of the field handouts via plant walk-down for this project proved to be very beneficial.

- Field operators are regularly assessed on their ability to successfully complete procedures and handouts as written. In contrast to assessing the operator's ability, the purpose of validation activities is to evaluate aspects of the job, such as the timing of tasks, workload and the quality of procedures. Operations staff involved in the field walk-downs in this project were actively engaged, discussing ways in which to make execution of the field handout procedures more efficient and safer. As a result of the field walk-downs, a number of labelling, plant configuration, and procedural issues were identified and corrected.
- The objective performance measure of "time to complete a task" was used as a success/fail criterion for credited human actions. During the recent project, it was discovered that a credited action could not be completed in the required time for one job. The licensee conducted an engineering assessment to identify potential changes to plant configuration and the procedures were changed accordingly. The credited operator actions can now be completed within the required time.
- Walk-downs of field activities were conducted by pairs of field operators and observed by HF Specialists. The HF Specialists used a workload assessment tool (simplified NASA Task Load Index) [10] to assess workload during the walk-downs of procedures and integrated

validation exercise. The tool sought the field operator's input about the following aspects of workload: physical, mental, effort, frustration, performance, and time pressure.
    - The workload assessment tool was useful for structuring discussions about the work, challenges encountered, and opportunities for improvement.
    - When quantitative ratings for any aspects of work exceeded a pre-established point, HF Specialists initiated additional discussion with the operators about possible improvements in an attempt to lower the workload of the task.
- The most conservative timing measurements obtained during validation activities were used to develop event timelines and to assess the feasibility of completing credited operator actions within the required time.
- When evaluating the timing of tasks, it is important to include the time required to obtain, don and use personal protective equipment (PPE). The simulation of tasks while wearing PPE contributes to the overall understanding of task workload.
- Pre-job briefings must also be assessed during the field walk-downs. The time to complete the emergency task briefing and the various aspects of workload should be considered.

The final validation exercise was a full-scale integrated response to the event involving operations staff from the main control room and field.

- The integrated validation exercise was very resource-intensive from both the licensee and regulatory perspectives. However, there were several benefits.
    - The exercise identified issues of communication, command-and-control and training which had not been identified during lower fidelity validation activities. The execution of the procedures in a high-fidelity validation exercise provided the opportunity to identify these issues.
    - Many exercises and drills are run from the MCR. However, in some events, the MCR may be uninhabitable. The integrated validation exercise was a MCR uninhabitable event that led operations staff to secondary control areas. Therefore, the exercise was a valuable opportunity to test communications systems and command and control protocols from secondary control areas.
- The exercise highlighted the need for exercise observers to have a thorough understanding of event progression and expected outcomes. Performance measures must be established prior to the exercise to objectively assess the degree of success of the activities [11]. Clear event termination criteria must also be established before beginning the exercise.

5.3 Project management

- For this large project, which required regulatory review and approval, CNSC involvement from the early stages of the project was essential. Open discussions and mutual respect for the goals of all stakeholders helped to ensure that the methodological issues were resolved before resources were spent implementing the method. CNSC involvement included regular

update meetings, technical discussions, and CNSC observation of field walk-downs and the integrated validation exercise.

- The analysis and validation of the MSC occurred over several months and required a considerable investment of resources. The licensee made significant progress once they organized this study as a project and funded it accordingly.
- The licensee assigned a senior manager to oversee the project's completion. This senior manager had the authority to commit resources, allocate funding and ensure commitment of higher levels of the organization.
- To ensure the basis for the MSC is readily available, key documentation from this project is referenced in the licensee's MSC document. By referencing the analysis and validation reports in the MSC document, the knowledge gained will be readily retrievable by licensee and CNSC staff in the future.

6. Conclusions

A thorough analysis to identify the most resource intensive conditions for all work groups and subsequent validation of the results provides confidence that a nuclear facility has an adequate number of staff with the appropriate qualifications on-site at all times. The analysis also demonstrates that the licensee understands how the MSC staffing levels will support the safe operation of the plant during normal operations through to the most resource intensive events. Given that operator actions in the MCR and the field may be required for successful mitigation of an event, it is imperative that this analysis and validation are conducted. Without this, uncertainty remains regarding the availability of sufficient qualified staff during event mitigation. It is clear that an evidence-based minimum staff complement provides a critical safety function for normal operations and event response.

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