

A Study on Human Factors Evaluation of Control Room Staffing Based on NUREG-1791

Young Do Koo *, Tongil Jang, Sa Kil Kim

Korea Atomic Energy Research Institute, 989-111 Daedeok-daero, Yuseong-gu, Daejeon, Republic of Korea 34057

*Corresponding author: jerrykoo@kaeri.re.kr

***Keywords :** control room staffing, human factors evaluation, NUREG-1791

1. Introduction

In small modular reactors (SMRs), control room staffing is one of the significant design issues in SMRs since it is not compatible with current regulatory requirements or nuclear power plant (NPP) industrial practices. From the perspective of human factors engineering (HFE), whether control room staffing in SMRs is reasonable can be now determined based on the criteria of HFE evaluation. However, the control room staffing in SMRs would not be fully assessed by the current criteria for HFE evaluation due to characteristics of the control room staffing in SMRs (e.g., one operator for multiple modular reactors, one control room for single staffing, and so on), different from large conventional NPPs. Therefore, complementary (or supplementary) HFE evaluation criteria need to be additionally adopted in determining reasonableness of the control room staffing in SMRs.

This study was carried out to elicit potential criteria for HFE evaluation of the control room staffing in SMRs based on existing evaluation methods and results, which ultimately aimed to aid to establish regulatory review criteria.

2. Methods

Until now, case studies on human factors evaluation of the control room staffing in SMRs are not enough or not sufficiently open to be analyzed for establishing clear and comprehensive the criteria. The study focused on exclusively on methods and application examples from the U.S. Nuclear Regulatory Commission (NRC).

2.1 Guidance for Reviewing Adequacy of Control Room Staffing

In the U.S. NRC, NUREG-1791 [1] was introduced to be used for assessing exemption requests from the regulatory requirements of minimum control room staffing levels (e.g., 10 CFR 50.54(m)). In the NUREG-1791 guidance, review process, elements, and criteria were represented for regulators to assess novel (or alternative) staffing levels which are beyond the scope of the regulatory requirements. NUREG-1791 is additionally applied in evaluating staffing levels in SMRs when reviewing HFE activities with NUREG-0711 [2], as a short-term solution under the current regulatory requirements.

DRO-ISG-2023-02 (augmented NUREG-1791 [3]) is being developed to assess staffing levels in advanced reactors including SMRs within the scope of reviewing staffing and qualifications (S&Q) in NUREG-0711. In the DRO-ISG-2023-02 document, review process, elements, and criteria for assessing staffing levels will be provided, as augmented NUREG-1791 which is very similar to the existing NUREG-1791. However, they are not focused on assessing exemption requests, but they are being comprehensive to assess staffing levels.

The purpose of the documents were different regarding its regulatory application. However, the methods in each document are commonly based on review of HFE activities according to NUREG-0711. Also, both are intended to be adopted in the element of S&Q in NUREG-0711 for assessing staffing in SMRs over their intrinsic purpose. Through the NUREG-1791-based methods (i.e., NUREG-1791 and DRO-ISG-2023-02) in the S&Q element, adequacy of control room staffing levels is determined depending on results of human performance from human-in-the-loop tests in advance of integrated system validation.

In the U.S. NRC, the NUREG-1791 method was considered as a short-term solution for addressing the staffing levels in SMRs beyond the regulatory requirement. For now, it seems that the NUREG-1791-based methods become a potential solution to fundamentally address diverse staffing levels in SMRs with regard to HFE, regardless of regulatory application (e.g., exemption requests).

2.2 Methodologies of Staffing Model Evaluation Based on NUREG-1791

For staffing levels of light water SMRs as well as non-water reactors (e.g., high-temperature gas reactors (HTGR) or liquid metal-cooled), the methodologies based on the NUREG-1791 method were considered by the applicants, and (being) reviewed by the U.S. NRC regulators. In the study, four case studies on human factors evaluation of the control room staffing, which were open to the public, were analyzed (refer to Table I).

In the case of staffing levels in the NuScale, as light water SMRs, results from the methodology based on the NUREG-1791 were adopted and reviewed in the S&Q element of NUREG-0711. Six and, subsequently, three control room operators for twelve modular reactors in the control room were evaluated through the review process, elements, and criteria described in NUREG-

1791 and NUREG-0711 Rev.3 [4], and, in turn, approved the proposed staffing levels considering human performance results through the final safety evaluation report (FSER) [5].

Xe-100 consists of four HTGR units at a site, and is controlled by three operators in one control room. X-energy, developer of Xe-100, submitted the topical report of staffing analysis methodology in accordance with NUREG-1791 and NUREG-0711 Rev.3 [6]. The U.S. NRC regulators evaluated the methodology for Xe-100 staffing through request for additional information and considered acceptability of the proposed methodology in the FSER [7].

Liquid metal-cooled Aurora powerhouse reactors being developed by Oklo have not specified the number of staffing levels and reactor units. However, Oklo is being developed staffing evaluation methodology for justifying the proposed staffing from the 10 CFR 50.54(m) mainly based on NUREG-1791, DRO-ISG-2023-02, and NUREG-0711 Rev.3 in the topical report [8]. Until now, the official documents for reviewing the methodology were not published by the U.S. NRC.

For staffing levels of pebble bed modular reactor (PBMR), whether to request exemption of the proposed staffing levels from 10 CFR 50.54(m) was discussed. The U.S. NRC regulators decided that the staffing levels were able to be addressed by 10 CFR 50.54(m), and finalized that there was no need exemption requests [9].

Table I: Analysis of staffing levels from four case studies

	Nu-Scale	Xe-100	Aurora	PBMR
Novel staffing from 10 CFR 50.54(m)	O	O	O	X
Staffing evaluation based on NUREG-1791	O	O	O	X
FSER published	O	O	X	X

3. Criteria for Human Factors Evaluation of Staffing

In the study, complementary criteria were elicited for human factors evaluation for staffing levels considering state-of-the-art HFE review guidelines, case studies of the staffing evaluation methodologies, and the official review comments from the U.S. NRC regulators, which aimed to be reflected in review process and criteria based on the NUREG-1791-based methodologies.

For reviewing novel/alternative control room staffing levels in domestic light water-cooled SMRs, complementary criteria, including reviewing the scope of justification for staffing and qualifications, concept

of operations, operational conditions, HFE program activities, and performance-based testing of staffing levels, were represented at an exploratory level.

4. Conclusions

In the study, complementary criteria for human factors evaluation of control room staffing in SMRs were elicited at an exploratory level, in order to identify potential regulatory HFE review criteria for the control staffing. By additional analysis of case studies and confirming needs from HFE regulators, the potential criteria for reviewing the control room staffing in a domestic light water-cooled SMR will be suggested, and then documented to aid to establish regulatory HFE review criteria by regulators. In developing the potential criteria for reviewing the control room staffing, design-specific considerations of a domestic light water SMR and comments from the U.S. NRC reviewer will be followed.

REFERENCES

- [1] J. Persensky, C. Plott, and V. Barnes, NUREG-1791: Guidance for Assessing Exemption Requests from the Nuclear Power Plant Licensed Operator Staffing Requirements Specified in 10 CFR 50.54(m), U.S. NRC, 2005.
- [2] J. M. O'Hara, J. C. Higgins, S. A. Fleger, and P. A. Pieringer, NUREG-0711: Human Factors Engineering Program Review Model, U.S. NRC, 2012.
- [3] DRO-ISG-2023-02: Draft Interim Staff Guidance Augmenting NUREG-1791, "Guidance for Assessing Exemption Requests from the Nuclear Power Plant Licensed Operator Staffing Requirements Specified in 10 CFR 50.54(m)," for Licensing Commercial Nuclear Plants under 10 CFR Part 53, U.S. NRC, 2024.
- [4] J. Osborn, NuScale Power, LLC - Submittal of "NuScale Control Room Staffing Plan," TR-0420-69456, Revision 1, NuScale Power, 2020.
- [5] Safety Evaluation for NuScale Power, LLC, Control Room Staffing Topical report TR-0420-69456 Public, U.S. NRC, 2021.
- [6] S. Vaughan, Submittal of X Energy, LLC (X-energy) Xe-100 Licensing Topical Report: Control Room Staffing Analysis Methodology, Revision 2 and Associated Implementation Plans Accepted Version, X-energy, 2023.
- [7] J. Vazquez, X Energy, LLC - Safety Evaluation for Xe-100 Licensing Topical Report Control Room Staffing Analysis Methodology, Rev. 2, U.S. NRC, 2023.
- [8] Enclosure 3 - "Staffing Plan Validation Methodology" Topical Report (Non-Proprietary), Oklo, 2026.
- [9] Operating Staffing Requirements under 10CFR 50.54 as Applicable to a Pebble Bed Modular Reactor (PBMR) Facility, Exelon, 2003.