Review of Domestic and International Regulatory Frameworks for Licensed Reactor Operator Staffing Requirements

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1. Introduction

Licensed operator staffing requirements are intended to ensure that the operating organization and staffing are sufficient to perform the monitoring, decision-making, control, and supervisory functions necessary during normal operation and accident conditions. Accordingly, the number of licensed operators is closely related to the operating organization, shift crew composition, operator qualifications and training, operating procedures, and the human factors engineering design of the control room.

In Korea, the Nuclear Safety Act requires that at least one Senior Reactor Operator (SRO) and one Reactor Operator (RO) be engaged in reactor operation at all times for each power reactor [1]. This reactor-based minimum staffing requirement has been applied primarily in the context of the unit-specific operating concept of conventional large nuclear power plants. However, with the emergence of new reactor designs featuring multiple modules, integrated control rooms, passive safety systems, and high levels of automation, regulatory issues have arisen as to whether the existing requirement can be applied in the same manner and what technical basis should be used to justify and review alternative staffing arrangements that reflect design-specific characteristics.

In the United States, 10 CFR 50.54(m) specifies the minimum number of licensed operators based on the number of operating reactors and the configuration of control rooms [2]. When an applicant proposes a staffing arrangement that differs from these requirements, an exemption process is available under 10 CFR 50.12 and NUREG-1791, through which the concept of operations, function allocation, task analysis, job definitions, staffing plan, and validation results are reviewed [2,4]. Regulatory experience with staffing for multi-module plants has also been accumulated through the review of the NuScale design [5]. More recently, Part 53 has incorporated a design-specific staffing approach based on analysis and validation into the regulatory framework [6].

This paper compares the regulatory frameworks for licensed reactor operator staffing in Korea and the United States, with particular emphasis on 10 CFR 50.54(m), the exemption review framework established in NUREG-1791, and its application to the NuScale design. The different approach used in Japan for managing reactor operating personnel is also considered a reference case. Based on this review, regulatory considerations for evaluating licensed operator staffing requirements applicable to new reactor designs in Korea are identified.

2. Licensed Reactor Operator Staffing Requirements in Korea

2.1 Structure of the Regulatory Framework

In Korea, licensed reactor operator staffing requirements are established through a regulatory structure in which the basic requirements are specified in statutes and Nuclear Safety and Security Commission regulations, while detailed shift crew staffing is prescribed in the plant-specific Technical Specifications [1]. At the statutory level, the Nuclear Safety Act requires each licensee of a power reactor to have at least one SRO and one RO engaged in reactor operation at all times for each reactor [1]. The Act also requires the technical capability necessary for the operation of a power reactor as a condition for an operating license and establishes the basic licensing framework and categories of reactor operator licenses, including SRO and RO licenses [1].

The subordinate regulation, the Rules on Technical Standards for Nuclear Reactor Facilities, Etc., requires a licensee of a power reactor to establish an operating organization necessary for the safe operation of the facility and to maintain qualified personnel, including SRO and RO license holders [1]. Detailed shift crew composition is specified in the plant-specific Technical Specifications, which establish the minimum numbers of SROs, ROs, and auxiliary operators according to the applicable operating mode.

A notable feature of this framework is that the numerical minimum staffing requirement for licensed operators is prescribed directly in the Act, rather than in subordinate regulations or plant-specific documents. Accordingly, while the Technical Specifications may require staffing levels above the statutory minimum, it is difficult to establish staffing below that minimum on the basis of reactor design characteristics or the level of automation. In addition, the current statutory framework

does not explicitly provide a separate exemption or alternative approach process through which an operator may propose a staffing arrangement different from the statutory minimum and the regulatory authority may review and approve its acceptability.

2.2 Historical Development of Staffing Requirements

The current licensed reactor operator staffing requirements were established through a series of amendments to the former Atomic Energy Act [1]. The major developments are summarized in Table I.

The numerical requirement to assign at least one SRO and one RO has remained in place since its introduction in 1982, and the 1995 amendment explicitly established "each reactor" as the unit of application [1]. Accordingly, the current requirement determines the minimum number of licensed operators primarily on the basis of the number of reactors, rather than the number of control rooms or whether multiple reactors are operated in an integrated manner. As a result, when this framework is applied to a design in which multiple reactor modules are operated from a single control room, the statutory minimum staffing level may increase with the number of modules, regardless of the actual operating functions to be performed.

3. Licensed Reactor Operator Staffing Requirements and Exemption Review Framework in the United States

3.1 Codification of Minimum Licensed Operator Staffing Requirements

Following the Three Mile Island Unit 2 accident in 1979, the United States strengthened regulatory requirements related to operator decision-making and response, training, and shift crew staffing [3]. As part of the subsequent regulatory actions, the NRC established shift staffing criteria and, in 1983, amended 10 CFR 50.54(m) to specify the minimum numbers of SROs and ROs required per shift based on the number of operating reactors and the configuration of control rooms [2,3].

In addition to the minimum staffing table, 10 CFR 50.54(m) requires an SRO responsible for overall plant operation to remain onsite whenever fuel is loaded in any reactor, an SRO to be present in the control room for each operating reactor, and an RO or SRO to be present at the controls for each reactor containing fuel. It also requires direct supervision by an SRO for core alteration activities [2]. These requirements are intended to ensure not only minimum staffing levels, but also the continuous availability of monitoring, supervisory, and control functions within the operating crew.

3.2 Exemption Review Framework under NUREG-1791

The minimum staffing table in 10 CFR 50.54(m) addresses combinations of up to three reactor units and a limited number of control room configurations and, therefore, is not directly applicable to designs in which multiple reactor modules are operated from a single control room [2]. An applicant proposing a staffing arrangement that differs from these requirements must obtain an exemption under 10 CFR 50.12 [2]. NUREG-1791 provides review guidance for evaluating the technical acceptability of such exemption requests [4].

The major review elements of NUREG-1791 consist of: (1) review the Exemption Request, (2) review of the Concept of Operations, (3) review the Operational Conditions, (4) review Operating Experience, (5) review the Functional Requirements Analysis and Function Allocation, (6) review the Task Analysis, (7) review the Job Definitions, (8) review the Staffing Plan, (9) review of Additional Data and Analyses, (10) review the Staffing Plan Validation, and (11) a determination the Acceptability of the Exemption Request [4].

A key feature of this review framework is that the acceptability of a proposed staffing arrangement is evaluated not simply by comparing the number of operators, but on the basis of design characteristics, the level of automation, operator functions and tasks, and actual operating crew performance [4]. The applicant is also responsible for demonstrating the technical basis for the exemption and must show, through the concept of operations, function allocation, task analysis, staffing plan, and validation results, that the proposed staffing arrangement does not adversely affect safety [4].

3.3 Application to NuScale

NuScale, which was designed to operate up to 12 reactor modules from a single control room, is a representative case in which the staffing review approach of NUREG-1791 was applied [5]. Table II summarizes the main features of the NRC-accepted licensed operator staffing arrangements for NuScale.

During the standard design certification review, NuScale proposed a six-member licensed operator crew consisting of three SROs and three ROs to operate up to 12 modules [5]. The staffing plan was developed and validated in accordance with NUREG-0711, NUREG-1791, and NUREG/CR-6838, and scenario-based Staffing Plan Validation testing was performed [5]. The NRC concluded that the operating crew could safely and reliably operate up to 12 modules and associated facilities from a single control room and incorporated the staffing arrangement into the design certification together with an exemption from 10 CFR 50.54(m) [5].

NuScale subsequently proposed a three-member licensed operator staffing plan consisting of two SROs

and one RO through an approved topical report. Its technical basis was also accepted by the NRC based on additional validation testing and supporting analyses [5]. However, approval of the topical report does not automatically authorize its use by all licensees; actual implementation requires separate approval or an exemption, as applicable, under the relevant licensing process.

The NuScale case demonstrates that a staffing arrangement that differs from the numerical requirements in the regulations is not simply a reduction in staffing or a discretionary regulatory relaxation. Rather, it is based on demonstrating operating crew performance through analyses of design automation and passive safety features, operator functions, tasks, and workload, together with validation using representative operational scenarios.

3.4 Regulatory Changes under Part 53

Under the Part 50 and Part 52 licensing pathways, the United States retains the fixed minimum staffing requirements of 10 CFR 50.54(m) as the baseline, while allowing exemptions or design-specific alternative requirements where appropriate [2,4]. In contrast, Part 53 does not rely on a fixed minimum staffing table. Instead, it requires applicants to develop design-specific staffing plans based on human factors analyses and evaluations and to obtain NRC approval of those plans through the licensing process [6].

In particular, the staffing requirements in Part 53 require analyses demonstrating that the positions, responsibilities, and staffing levels are sufficient to support plant operation and the maintenance of safety functions [6]. This can be viewed as incorporating into the general licensing framework an analysis-based approach similar to that used under NUREG-1791, including the consideration of the Concept of Operations, function allocation, task analysis, and staffing plan validation.

4. Comparative Review and Conclusions

Both Korea and the United States require sufficient licensed operators or operating personnel to ensure the safe operation of nuclear reactors, but they differ in how staffing arrangements that deviate from the minimum requirements may be accepted. In Korea, the law directly requires at least one SRO and one RO for each reactor, and the current statutory framework does not provide an explicit pathway for approving an alternative staffing arrangement through a separate technical demonstration [1]. In the United States, the minimum staffing requirements of 10 CFR 50.54(m) serve as the baseline, while alternative staffing arrangements may be applied through exemptions or design-specific alternative requirements. Their acceptability is evaluated based on factors such as the Concept of Operations, function allocation, task analysis, workload, and validation results [2,4].

Unlike Korea and the United States, Japan does not require individual control room operators to hold national licenses equivalent to RO or SRO licenses, nor does it prescribe uniform numerical minimum staffing requirements. Instead, the required operating personnel are managed through a qualification framework for reactor operation managers and plant-specific operational safety programs [7]. This provides a useful reference showing that regulatory approaches to operating personnel may differ depending on the national licensing and regulatory framework.

For new operating concepts, such as multi-module plant and integrated control room, it is necessary to consider whether minimum staffing requirements based solely on the number of reactors adequately reflect design characteristics and actual operating functions. Rather than focusing only on whether the number of licensed operators should be reduced, it is important to consider whether a regulatory review framework is needed to allow alternative staffing arrangements that account for design-specific characteristics, together with the application of the existing minimum staffing requirements.

The U.S. exemption review framework and the NuScale case demonstrate the importance of technical justification by the applicant and regulatory review and confirmation when a staffing arrangement that differs from the regulatory requirements is proposed [4,5]. In Korea, it is also necessary to consider amendments to the current licensed operator staffing requirements to accommodate new design and operating concepts, such as multi-module plant, and to establish a regulatory framework for demonstrating and reviewing the acceptability of alternative staffing arrangements.

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[6] U.S. NRC, Risk-Informed, Technology-Inclusive Regulatory Framework for Advanced Reactors, 10 CFR Part 53, Final Rule, 2026.
[7] Act on the Regulation of Nuclear Source Material, Nuclear Fuel Material and Reactors, Articles 43-3-24 and 43-3-26, Japan; Regulation on the Installation and Operation of Commercial Power Reactors, Articles 87 and 95, Japan.

Table I. Historical development of licensed reactor operator staffing requirements in Korean legislation

Year	Legislation/Amendment	Major Changes
1958	Enactment of the Atomic Energy Act	· Introduction of a licensing system for reactor operators; no numerical staffing requirement
1982	Full amendment of the Atomic Energy Act	· Introduction of a system requiring the designation of a “reactor operation supervisor” from among SRO license holders · Requirement for at least one SRO and one RO to be continuously engaged in reactor operation
1995	Partial amendment of the Atomic Energy Act	· First introduction of the phrase “for each reactor”
1999	Partial amendment of the Atomic Energy Act	· Deletion of provisions related to the reactor operation supervisor (Articles 26–28) · Transfer of the staffing requirement to Article 29(3), substantially establishing the current wording
2011	Enactment of the Nuclear Safety Act	· Transfer of the requirement into the current statutory framework without substantive change

Table II. NRC-Accepted NuScale Licensed Operator Staffing Arrangements [5]

Category	Applicable Configuration	SRO	RO	Total	Regulatory Significance
General Requirements of 10 CFR 50.54(m)	No directly applicable requirement for 12 modules operated from a single control room	-	-	-	Alternative requirements or an exemption required
NuScale Design Certification	Up to 12 modules operated from a single control room	3	3	6	Incorporated into the design certification
Topical Report	Up to 12 modules operated from a single control room	2	1	3	NRC-approved technical basis; separate licensing action required for implementation