

## **A Graded Safety Culture Oversight Framework for Korea's Nuclear Facilities: Lessons from the IAEA, the U.S. NRC, and the CNSC**

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### **1. Introduction**

Safety culture within organizations operating nuclear facilities is a cornerstone of nuclear safety that the International Atomic Energy Agency (IAEA) and nuclear regulatory bodies have consistently emphasized. Major events—including the Chernobyl accident (1986), the Fukushima Daiichi accident (2011), and the Kori-1 station blackout (SBO) incident (2012)—have underscored its importance. There is growing recognition that sustaining and improving licensees' safety culture requires regulatory oversight in addition to the licensee's own efforts. Because safety culture encompasses both organizational practices and personnel attitudes, regulatory bodies can, through oversight, prompt licensees to reflect on and strengthen safety culture.

Korea's nuclear regulatory body recently underwent an IAEA Integrated Regulatory Review Service (IRRS) mission and received Recommendation R7 to establish regulatory requirements for safety culture and incorporate them into the national regulatory framework [1]. This has created an imperative to overhaul the domestic safety culture oversight framework for nuclear facilities.

Although Korea has gradually introduced elements of safety culture oversight, implementation remains limited and uneven across facility types. In 2014, amendments to the Enforcement Decree and Enforcement Rule of the Nuclear Safety Act added safety culture elements to the scope of the Periodic Safety Review (PSR) for nuclear power plants (NPPs). In 2020, a Notice of the Nuclear Safety and Security Commission (NSSC) titled "Regulation on Reporting and Public Disclosure of Accidents and Incidents at Nuclear Facilities" was revised to provide the basis for special inspections on safety culture. In 2021, when PSR was introduced for radioactive waste management facilities, safety culture was included among the PSR items. However, in the absence of a comprehensive blueprint, these improvements were made piecemeal. As a result, safety culture oversight is applied inconsistently across facility types, without integrated consideration of risk significance or regulatory impact.

This study analyzes international trends in safety culture oversight—drawing on the IAEA safety standards and approaches from leading countries such as the United States and Canada—and proposes a safety

culture oversight scheme for Korea's nuclear facilities. We focus on a graded approach that tailors oversight to facility characteristics, importance, and risk. The aim is to align with international standards and good practices while deploying limited regulatory resources efficiently to elevate safety culture across the sector.

### **2. International trends in safety culture oversight for nuclear facilities**

#### *2.1 IAEA safety standards related to safety culture*

The IAEA treats safety culture as a fundamental principle of nuclear safety and reflects it across multiple documents. In the top-tier Fundamental Safety Principles (SF 1), Principle 3 ("Leadership and management for safety") calls for fostering safety culture across all nuclear facilities [2]. General Safety Requirements (GSR) Part 2 further requires licensees to foster, periodically assess, and continuously improve organizational culture to support continual improvement in safety culture. In addition, a range of requirements documents—GSR Part 3, SSR 2/2, SSR 3, SSR 4, GSR Part 5, among others—include safety culture related provisions [3–8].

While these standards articulate safety culture principles and requirements across various facility types, they do not provide a regulator-ready, facility-differentiated graded approach. The breadth of safety culture provisions also varies: for example, SSR 3 (research reactors) contains more explicit provisions than SSR 2/2 (NPP operations), and although most facility standards address organizational responsibilities, safety policy, and competence and training, GSR Part 5 (radioactive waste management) specifies only organizational responsibilities. In short, the IAEA sets expectations for safety culture across facilities but stops short of prescribing a facility-differentiated graded scheme for oversight.

#### *2.2 Safety culture oversight by the U.S. NRC*

The U.S. Nuclear Regulatory Commission (NRC) promotes safety culture through a Safety Culture Policy Statement rather than codified requirements [9]. Oversight is differentiated by facility type: (i) NPPs; (ii)

non-power facilities under direct NRC jurisdiction; and (iii) facilities regulated by Agreement States.

For NPPs, the NRC oversees safety culture through the Reactor Oversight Process (ROP) and traditional enforcement. Within the ROP, two mechanisms apply. First, each plant's overall performance is placed into one of four Action Matrix columns; beginning with Column 2, the NRC conducts additional inspections focused on safety culture commensurate with the column. Second, the NRC assigns cross-cutting aspect (CCA) codes to inspection findings and performs trending analyses to determine whether a cross-cutting issue (CCI) exists. If a CCI is sustained, the NRC may require the licensee to conduct a safety culture assessment, followed by additional inspections. In parallel, through traditional enforcement, issues identified during inspections—such as safety-significant problems or rule violations—can lead to Alternative Dispute Resolution (ADR) and a Confirmatory Order, requiring a safety culture assessment and corrective actions, with subsequent follow-up inspections.

For non-power facilities under NRC jurisdiction (e.g., research reactors, fuel cycle facilities, and spent fuel storage installations), safety culture oversight is exercised through traditional enforcement. For example, after the 2021 event at the NIST research reactor involving fuel damage, release of radioactive material, and declaration of an alert, the NRC used ADR and issued a Confirmatory Order in 2022; the licensee conducted a safety culture assessment and implemented improvements, and the NRC carried out additional inspections in 2023–2024 to verify implementation. By contrast, for facilities regulated by Agreement States (e.g., many small radioisotope users, radiation generating devices, and low level waste disposal facilities), there is no direct federal level safety culture oversight by the NRC.

In sum, the U.S. approach falls into three categories: (1) NPPs—oversight via the ROP plus traditional enforcement; (2) non-power facilities under NRC—oversight via traditional enforcement; and (3) Agreement State facilities—no direct federal oversight. The NRC thereby elevates the importance of safety culture through policy while relying on flexible, inspection and enforcement based oversight rather than codified requirements.

### *2.3 Safety culture oversight by the CNSC*

Unlike the U.S., the Canadian Nuclear Safety Commission (CNSC) has established explicit regulatory requirements for safety culture, issuing REGDOC 2.1.2 in 2018 [10]. The requirements apply to Class I nuclear facilities, imposing an obligation to foster safety culture; for NPPs, there is an additional requirement to conduct a safety culture assessment every five years. Furthermore, REGDOC 1.1.2 and REGDOC 1.1.3 require license applications for nuclear facilities to

address safety culture [11, 12], and REGDOC 2.3.3 requires safety culture to be evaluated as part of the PSR [13]. Thus, safety culture is considered across the regulatory continuum—from licensing to operational inspections to periodic reviews.

The CNSC's graded oversight can be grouped into three tiers. First, for NPPs, both the obligation to foster safety culture and the obligation to conduct regular assessments apply. Second, for non-power Class I facilities (e.g., research reactors, fuel cycle facilities, radioactive waste processing and storage facilities, and large radiation generating devices), licensees must foster safety culture, but—unlike NPPs—are not universally required to conduct periodic self assessments; the regulator may evaluate safety culture during inspections and require improvements as needed. Third, for Class II facilities (e.g., medical and industrial radioisotope uses and small radiation generating devices), no separate safety culture requirements are applied. This graded strategy tailors expectations to facility scale and risk and, by embedding safety culture throughout licensing, inspections, and PSR, provides a robust governance framework—distinct from the U.S. approach and highly instructive for Korea.

## **3. Options for safety culture oversight in Korea**

### *3.1 Re-examining the current domestic framework*

Since 2014, Korea has incrementally introduced safety culture provisions for certain facility types. For NPPs and research reactors, safety culture is evaluated during PSR and, in operation, when a reportable event is upgraded by one level due to safety culture deficiencies, a special inspection focused on safety culture may be conducted. Consequently, safety culture oversight for NPPs and research reactors currently rests on two pillars—PSR and special inspections.

By contrast, for fuel cycle facilities, radioisotope (RI) users, and radiation generating devices, only special inspections apply; and for radioactive waste management facilities, safety culture is addressed in PSR but these facilities are not subject to safety culture special inspections, leaving no post-event mechanism. In effect, oversight has evolved—historically rather than by design—into an imbalanced four tier structure.

This status quo presents multiple issues: lack of equity and consistency across facilities and the absence of clear criteria for applying oversight. Without principles defining which facilities should be subject to which level of safety culture oversight, gaps can arise. Reflecting these concerns, the IAEA's 2014 IRRS follow-up mission and 2024 IRRS mission recommended establishing national level safety culture requirements. A comprehensive redesign consistent with international standards and leading practices is therefore necessary.

### *3.2 A graded, facility-specific oversight scheme*

Drawing lessons from the international cases above, we propose grouping facilities by importance and applying graded safety culture oversight to each group. Group assignment reflects potential radiological consequences, process complexity, and the extent of societal impact.

Group 1 (Priority oversight — NPPs and research reactors): Given their higher potential radiological consequences and broad societal impact, these facilities should be subject to the most comprehensive oversight across the facility lifecycle. Concretely, require license applications to address safety culture matters; include safety culture in PSR scope; add safety culture items to routine inspections; and, when a reportable event is upgraded by one level due to safety culture deficiencies, conduct special inspections to identify organizational vulnerabilities and drive improvements. In effect, safety culture is integrated across the full regulatory cycle (licensing–inspection–assessment–special inspections).

Group 2 (Targeted oversight — fuel cycle facilities and radioactive waste management facilities): Although lower risk than Group 1, these facilities still present significant hazards. Manage safety culture through PSR and event driven special inspections. For fuel cycle facilities—once PSR is institutionalized—include safety culture within PSR scope. For waste management facilities, revise the NSSC Notice (“Regulation on Reporting and Public Disclosure of Accidents and Incidents at Nuclear Facilities”) to provide the legal basis for conducting safety culture special inspections when events are upgraded by one level due to safety culture deficiencies. This approach parallels the CNSC’s practice of overseeing safety culture at major facilities via PSR and inspections, bringing Korea closer to international norms.

Group 3 (Licensee self-management — small, low risk facilities such as RI users, radiation generating devices, nuclear material users): These facilities are widely distributed across hospitals, universities, and industry. From a radiation protection perspective they are routine oversight targets, but within the nuclear sector they are lowest risk. Although current reporting rules can, following event rating, designate such facilities for safety culture special inspections, few countries impose dedicated safety culture requirements at this scale. To focus regulatory resources on higher risk facilities and preserve proportionality, maintain minimal safety culture oversight for Group 3 at current levels.

In summary, the proposed graded scheme aligns with domestic and international realities. For Group 1, existing PSR and special inspections are maintained and expanded to licensing and routine inspections, strengthening oversight. For Group 2, partially applied measures are codified and supplemented, filling gaps.

For Group 3, the status quo is maintained to avoid unnecessary regulatory burden.

## **4. Conclusions**

This study examined international trends—centered on the IAEA, the U.S., and Canada—to identify key issues in safety culture regulation: whether to codify safety culture (explicit requirements, as in Canada, versus policy level statements, as in the U.S.); how to design graded oversight by facility type; and how to integrate safety culture into regulatory instruments (licensing, inspections, PSR). In Korea, the most pressing problems are the absence of clear safety culture requirements and the inconsistent application of oversight. As a remedy, we propose a graded, facility-specific framework: comprehensive oversight across the lifecycle for Group 1 (NPPs and research reactors); targeted oversight via PSR and special inspections for Group 2 (fuel cycle facilities and waste management facilities); and maintenance of current practice for Group 3 (low risk radiation uses).

Our recommendations provide strategic direction for domestic policy and a basis for future legal and institutional reforms. Implementing the IRRS recommendation will enhance the international credibility of Korea’s regulatory framework. Codifying safety culture requirements will address deficiencies and improve alignment with IAEA safety standards. A graded approach will enable efficient allocation of regulatory resources—concentrating oversight where risk is highest while encouraging autonomy and accountability in low risk areas. To implement this scheme, follow-on studies and detailed planning are required: identify necessary amendments to the Nuclear Safety Act, subordinate decrees and rules, and NSSC notices; develop group specific inspection guides and procedures; and train inspectors to strengthen safety culture assessment capabilities.

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