# APPLICABILITY OF THE NRC LIGHT WATER REACTOR LICENSING PROCESS TO SMRs

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## 1.0 INTRODUCTION

Since the first days of the nuclear era, researchers and designers have conceived and developed a wide variety of reactor concepts. A rich variety of theoretical analyses, experimental studies, and prototype reactors demonstrated that each of these approaches had its own set of advantages. The technology base included a range of coolant materials, moderators, fuel types, and system configurations. Nevertheless, as the nuclear power industry grew and evolved, plant designs focused on light water–cooled reactors of the boiling water reactor and Pressurized Water Reactor (PWR) type. Knowledge gained from operational experience was incorporated into each succeeding generation of reactors, and the plants became increasingly similar in their overall characteristics.

The regulations and regulatory guidance of the U.S. Nuclear Regulatory Commission (NRC) have evolved in response to these developments in plant design. In addition, the NRC continuously examines operating experience to identify opportunities for improvements in the regulatory process and enhancements to plant designs. As a result, the regulations and regulatory guidance of the NRC are focused largely on the current fleet of Light Water Reactor (LWR) designs.

Every new plant design presents its own set of challenges for the licensing process. This is true for single units seeking Operating Licenses (OLs) and standardized plants applying for Design Certifications (DCs).

The NRC makes use of time-tested regulatory processes to promote effectiveness and efficiency in its licensing reviews. These processes are supported by a wealth of regulatory guidance in the form of Regulatory Guides (RGs), the Standard Review Plan (SRP), and the consensus codes and standards produced by Standards Development Organizations (SDOs). As a result, the schedule, cost, and complexity of a licensing review can be greatly affected by the degree to which a plant concept deviates from existing designs.

Much of the design of a nuclear plant is independent of the type of reactor proposed. For example, the mechanical, structural, electrical, and Instrumentation and Control (I&C) characteristics of all Nuclear Power Plants (NPPs) are similar, as are the treatment of quality assurance, the environmental qualification, and the design for site hazards. The most challenging regulatory issues for a new reactor design tend to center on core and reactor coolant design, materials applications, system configuration, accident analysis, and containment. In addition, the conduct of Probabilistic Risk Assessment (PRA) and severe accident analysis can present new challenges.

Small and Medium Sized Reactors (SMRs) of a light water design differ in important ways from each other and from the current fleet of operating reactors. These designs incorporate innovative approaches to achieve simplicity, improved operational performance, and enhanced safety. Gas-cooled and liquid metal–cooled reactors represent an even greater departure from current designs and consequently greater challenges to the application of current regulatory guidance.

Several of the most challenging issues have been identified and analyzed in recent years. The next section of this paper will discuss this history in some detail. If SMR licensing is to succeed, these issues must be resolved to the satisfaction of the NRC and the public.

On the other hand, SMRs present an opportunity to develop a new generation of power plants with enhanced safety performance. Many of the designs make use of passive safety systems with simpler components, fewer dependencies, and less stringent operation/maintenance requirements. Some designs incorporate inherent safety features such as higher thermal inertia. In some cases, fast-moving accidents such as Loss-Of-Coolant Accidents (LOCAs) have been eliminated, and transient response is more benign. Some designs present less of a challenge in the severe accident arena and have favorable source term characteristics. These differences can ease the burden on operating staff and create opportunities for more effective accident management and should therefore result in a more efficient licensing process than that used for current LWR designs.

Light water reactor requirements provide assurance of safety system quality, capability, reliability, and redundancy commensurate with the safety characteristics of current designs. To the extent that SMR designs incorporate passive safety features, enhanced safety margins, slower accident response, and improved severe accident performance, opportunities to simplify and streamline the regulatory process and requirements should be considered.

## 2.0 BACKGROUND

The fundamental issues for *non-LWRs* have been detailed in SECY-03-0047 (Ref. 1). The staff identified seven issues and made recommendations for each:

1. "How should the Commission's expectations for enhanced safety be implemented for future non-LWRs?"
2. "Should specific defense-in-depth attributes be defined for non-LWRs?"
3. "How should NRC requirements for future non-LWR plants relate to international codes and standards?"
4. "To what extent should a probabilistic approach be used to establish the plant licensing basis?"
5. "Under what conditions, if any, should scenario-specific accident source terms be used for licensing decisions regarding containment and site suitability?"
6. "Under what conditions, if any, can a plant be licensed without a pressure-retaining containment building?"
7. "Under what conditions, if any, can emergency planning zones be reduced, including a reduction to the site exclusion area boundary?"

In assessing the options and developing the recommendations on the seven issues, the following general guidelines were employed by the staff:

- "Keep the risk to the population around a nuclear power plant site consistent with the Commission's 1986 Reactor Safety Goal Policy (51 FR 28044)."
- "Choose a risk-informed and performance-based approach, wherever practical, consistent with the Commission's 1995 Policy Statement on the Use of Probabilistic Risk Assessment Methods in Nuclear Regulatory Activities (60 FR 4 2622) and the March 11, 1999, White Paper on Risk-Informed and Performance Based Regulation."
- "Use a technology-neutral approach."
- "Use the Commission's four performance goals to assess the advantages and disadvantages of the options and to develop recommendations."
- "Consider previous Commission guidance on these issues."
- "Consider the practicality of the options and recommendations."

On June 26, 2003, the NRC approved the staff recommendations for issues 2, 4, 5, and 7. The NRC approved the staff's recommendation for issue 1 on implementation of the NRC's expectations for enhanced safety in future non-LWRs, with the exception of accounting for the integrated risk posed by multiple reactors at the same site.

The NRC disapproved the staff's recommendation for issue 6, related to the requirement for a pressure-retaining containment building, indicating that there was insufficient information for the NRC to prejudge the best options and make a decision on the viability of a confinement building. The staff was directed to develop performance requirements and criteria working closely with industry experts (e.g., designers, Electric Power Research Institute) and other stakeholders regarding options in this area, taking into account such features as core, fuel, and cooling systems design. Further, the staff was directed to pursue the development of functional performance standards and then submit options and recommendations to the NRC for this policy decision. These requirements have not yet been developed.

On August 20, 2004, the NRC published SECY-04-0157 (Ref. 2), which outlined the staff's proposed regulatory structure for new plant licensing and potentially new policy issues. The objective of the regulatory structure for new plant licensing is to provide a *technology-neutral approach* to enhance the effectiveness and efficiency of new plant licensing in the longer term (beyond the advanced designs currently in the preapplication stage). The staff is developing a regulatory structure with four major parts (as discussed in SECY-04-0157):

"(1) a technology-neutral risk-informed framework (to be documented in a NUREG report) that will provide guidance and criteria to the staff for the development of technology-neutral requirements

(2) the content for a set of technology-neutral risk-informed requirements that will be based on the guidance and criteria established in the technology-neutral framework NUREG

(3) a technology-specific framework (to be documented in a NUREG report) that will provide guidance and criteria for the staff on how to apply the technology-neutral framework and requirements on a technology-specific basis

(4) technology-specific RGs that will be derived from the implementation of the technology-specific framework and will provide guidance to licensees on how to apply the technology-neutral regulations on a technology-specific basis."

NUREG-1860 (Ref. 3) was published in December 2007 to establish the framework described in part (1). NUREG-1860 documents a "framework" that provides guidance to staff to develop a set of requirements that would serve as an alternative to 10 CFR 50 (Ref. 4) for licensing future NPPs. The framework does not represent a complete process since there are several policy and technical issues to be resolved. NUREG-1860 refers often to advanced reactor designs, which are interpreted in the document to be non-LWRs. There is no mention of light water designs beyond the current Generation III/III$^+$, such as NuScale and Babcock & Wilcox (B&W) mPower.

Developing the requirements must consider the applicability of each of the General Design Criteria (GDC) and other relevant requirements relative to the reactor design in question. For example, for liquid metal–cooled, pool-type reactors, i.e., Power Reactor Innovative Small Module (PRISM), the following requirements merit reconsideration:

- accident evaluation, GDC 4
- source term, GDC 60, as low as reasonably achievable (ALARA) [TID 14844 (TID 14844 replaced by SECY-92-127 (source term evaluation); NUREG-1465 (Ref. 5)]
- containment performance, GDC 16, 38, 39, 40, 41, 42, 43, 50–57
- emergency planning, (defense-in-depth philosophy)
- reactivity control system, GDC 26 (necessity for two independent systems)
- operator staffing and function (minimum staffing requirements)
- residual heat removal, GDC 34, safety-grade systems versus passive systems
- positive void coefficient of reactivity, GDC 11, (negative power coefficient).

The key documents used by the staff to complete a DC are 10 CFR 50, 10 CFR 52 (Ref. 6), and NUREG-0800 (SRP) (Ref. 7). The next step after DC, the combined OL, will involve the use of 10 CFR 51 (Ref. 8) and NUREG-1555 (Ref. 9). Currently, a combined OL application is submitted according to RG 1.206 (LWR edition) (Ref. 10) and Office Instruction NRO-REG-100 (Ref. 11). Similar documents do not yet exist for non-LWRs. Prior to operation, the Inspections, Tests, Analyses, and Acceptance Criteria (ITAAC) process must be completed. Chapter 14 of NUREG-0800 (SRP) establishes the ITAAC, but guidance for completion of ITAAC is not yet complete for any reactor design.

The documents discussed above must each be further reviewed for applicability and consistency relative to specific SMR designs and the NRC's policy for enhanced safety margins for advanced designs. The results of the review will likely be different for the specific design being considered, e.g., light water, gas, or liquid metal–cooled; metal or oxide fuel matrices.

Additionally, multi-module SMR sites should be accommodated by the combined OL process. Prototype and manufacturing licensing processes and definitions will also require review relative to specific SMRs.

There have been design reviews in the past. In 1992 General Atomics (GA) issued a report to the U.S. Department of Energy (DOE), "NP-MHTGR, Assessment of the Applicability of NRC Regulatory Guides and Branch Technical Positions." This report gives the flavor of the assessment that must be made for a new design. The following quote from the report clearly states the issue with respect to RGs and the GDC:

> "Since the RGs and BTPs [Branch Technical Positions] were developed by the NRC primarily for light water-cooled reactors, many of them are not directly applicable to HTGRs. It is, therefore, necessary to conduct an assessment of them for applicability to the New Production Modular High Temperature Gas-Cooled Reactor (NPMHTGR). Some of the RGs and BTPs will be found to be directly applicable to the NP-MHTGR, while others will be found to be not applicable at all. In general, however, most will be found to be applicable with qualification. In these cases the intent or spirit of the RG or BTP is applicable, but revisions to the guidance are needed to make it technically meaningful in the context of gas-cooled reactor technology."

The issue relative to RGs and the GDC for non-LWR designs is even larger than characterized since the reviews that have been done do not take into account the requirements of 10 CFR 52, the advent of risk-informed and performance-based regulation, or the environmental reviews that are necessary for a combined OL application.

The NRC position relative to liquid metal–cooled reactors is well outlined in NUREG-1368 (Ref. 12), published in 1994. The extensive review concluded that "on the basis of the review performed, the staff, with the NRC Advisory Committee on Reactor Safeguard (ACRS) in agreement, concludes that no obvious impediments to licensing the PRISM design have been identified." These two preapplication reviews reveal the effort required on the part of the designer/vendor and the regulator in the future as SMR designs become more common.

## 3.0 PROBLEM/ISSUE STATEMENT

Much of the NRC regulatory guidance and technical requirements apply equally well to SMRs as to the current generation of large LWR plants. The challenge is to define a safe, credible, and efficient process to ensure that the SMR designs meet the basic requirement of the Atomic Energy Act, i.e., to provide reasonable assurance of adequate protection of the public health and safety. Realistically, consistent with NRC policy, it will also have to be shown that the level of protection provided by an SMR is at least equivalent to, or better than, what is provided by current designs.

## 4.0 DISCUSSION AND ACTUAL WORK

All SMR designs deviate to a greater or lesser extent from the standard large-LWR template upon which the current regulatory framework is focused. Many of the differences relate simply to the small scale of these designs. Others relate to significant differences in the configuration of systems, structures, and components that are important to safety. SMR designs that are not LWRs have the additional factor of deviating in fundamental design concept: different coolant, different moderator. These factors lead to more fundamental differences with the current regulatory framework, i.e., different neutronic and thermal-hydraulic responses and different design-basis accidents. As a result, the certification of non-LWR designs will require specific deviations on a case-by-case basis from the requirements and guidance that currently govern the licensing of nuclear power reactors in the United States.

In some cases, an SMR design characteristic will deviate from regulatory guidance but will not violate a binding requirement. These include deviations from the provisions of the RGs, NRC policy statements, or the SRP. In these cases, approval for the deviation can be obtained by making an acceptable technical argument. The technical challenge may be significant in some instances, but the approval process is straightforward.

By contrast, if a design feature violates the specific provisions of an NRC regulation, the approval process becomes more complicated. The following sections discuss the options for obtaining approval in these cases.

### 1. BACK FIT

Some aspects of non-LWR designs present hazards to safety that are not covered by current NRC requirements. For example, liquid metal–cooled plants have the possibility of sodium fires. Engineered features to deal with such cases can be incorporated into the design and into the licensing basis of the plant in two ways. The first is for the applicant to incorporate the features voluntarily into the DC documents. These can then be endorsed in the staff's Safety Evaluation Report (SER). The second option is for the NRC staff to mandate a remedy for the hazard through 10 CFR 50.109 (Ref. 13), the backfit process. In either case, the resulting design feature would then be incorporated into the design through the 10 CFR 52 rulemaking process.

### 2. EXEMPTIONS

In some respects, SMR design characteristics are favorable to safety and will tend to justify less stringent application of current requirements. For example, some non-LWR designs are not susceptible to LOCAs and will not require an emergency core cooling system (ECCS). In such cases, the applicant would request relief under 10 CFR 50.12 (Ref. 14) or 10 CFR 52.7 (Ref. 15), the exemption process. To apply this process, the applicant must demonstrate that the deviation does not represent an undue risk to the public health and safety and that it is needed because a "special circumstance" exists. One example of a special circumstance that might apply to SMRs is that "application of the regulation in the particular circumstances would not serve the underlying purpose of the rule or is not necessary to achieve the underlying purpose of the rule." At this time, the exemption process (10 CFR 50.12 or 10 CFR 52.7) is the only NRC change process that can be applied by an SMR applicant to gain approval for deviations from NRC requirements.

In the history of regulation in the United States, the exemption process has been successfully applied numerous times, both for the initial licensing of plants and during their operational periods. Exemptions for any given plant have been infrequent, particularly in recent years since changes to certain regulations have eliminated some of the more frequent occasions for exemptions. The NRC has sought to avoid the excessive use of 10 CFR 50.12.

Moreover, exemption applications have generally been for changes that were limited in scope. For example, a plant might be exempted from in-service inspection for a specific pipe or weld but not for large portions of the plant. Many of the past exemptions were for minor changes to the schedules for containment leakage testing. The justifications for these exemptions were relatively straightforward and uncomplicated. There was no need to contemplate secondary impacts from approval of the request.

For SMR plants of LWR design, the number and complexity of needed exemptions may be modest. However, the exemptions needed for certification of non-LWR designs will deviate from these patterns in two respects: they may be numerous, and they may be complex. This situation will create two difficulties for the licensing process: (1) the effort on the part of the NRC and the applicant to grant approval of these exemptions will be significant and (2) the public perception associated with the issuance of so many complex exemptions may be unduly negative.

While the exemption process probably can be used judiciously for SMRs of LWR design, the licensing of non-LWR designs may require a different approach. Any new approach will require a time-consuming change to the Code of Federal Regulations (CFR) and will not be available in the near term. Sections 3 and 4 discuss two options for long-term changes to the CFR to accommodate the licensing of SMRs of the non-LWR variety.

## 3. TECHNOLOGY-NEUTRAL FRAMEWORK: GENERAL-SAFETY-STANDARDS OPTION

As discussed above, proposals have been made for enactment of technology-neutral regulations to govern the licensing of designs other than large LWRs (NUREG-1860). These regulations might be less specific than the requirements currently found in 10 CFR 50. Examples of this type of requirement can be found in International Atomic Energy Agency (IAEA) Safety Series Number NS-R-1 (Ref. 16). In this option, the details will be relegated to guidance documents such as the RGs or SRP.

In addition, the issuance of technology-specific regulatory guidance for each of the major non-LWR design types has been proposed. This guidance would be at the same level of specificity as the current regulations but would be appropriate to the features that are typical of that design type. The combination of the technology-neutral requirements with the technology-specific guidance will eliminate the need for multiple, complex exemptions in the licensing of non-LWRs.

The disadvantage of this approach is the difficulty of making a technical change to an NRC regulation. There have been numerous examples in the past of technical changes that have taken many years to enact. For example, the proposal to remove hydrogen recombiners from the design basis of large dry PWR containments was first introduced in the regulatory arena in 1992. In spite of wide agreement that the recombiners were of little safety significance, the rule change did not receive final approval until

2003. If one relatively modest change can require that much time and attention, the enactment of a new regulatory framework is likely to be complex and time-consuming.

## 4. TECHNOLOGY-NEUTRAL FRAMEWORK: PARITY OPTION

As noted above, the only option currently available for gaining approval of a deviation from a binding requirement is the exemption process. In this option, the licensee is exempted from meeting a requirement based on a demonstration of low public risk and the presence of "special circumstances." The implication of granting an exemption is that the design feature is deficient in some way but is acceptable because the safety impact is minimal. The granting of numerous exemptions has the disadvantage of raising the question whether the combined result of these minimal effects might be significant.

SMR designs are not deficient; they are in fact inherently safe in many ways. The parity option allows an applicant to gain license approval by demonstrating the inherent safety qualities of the design. The essence of this option is to enact an NRC change process that justifies deviations from the current regulations based on an integrated analysis of the fundamental features of the plant. The acceptance criteria for approval under the new change process would require demonstrating that the design provides a level of protection of the public health and safety that is equivalent to or better than what is provided by compliance with the current regulations.

The approval of a non-LWR design would still be technically complex under this proposal. The advantage is that the complexity will be dealt with in the NRC review process, not in the rulemaking process. Many options exist for facilitating the treatment of technical complexity in the context of the review process. Two examples of processes that have proved effective to gain NRC staff approval, in principal, for a new approach to achieving compliance and assuring safety are the industry consensus submittal and the topical report process, described as follows:

- *Industry Consensus Standards*: Review of consensus standards or Nuclear Energy Institute (NEI) task reports provide SER conclusions that can be relied on in individual licensing decisions. These industry consensus reports have been used on issues like fire protection, quality assurance, emergency planning action levels, operator training, and other administrative procedures. The industry and NRC can work toward a review structure for common issues in DC submissions, much the same way the industry Design Centered Working Groups (DCWGs) resolve common issues in DC, Reference Combined Construction and Operating License Application (R-COLA), and Standard Combined Construction and Operating License Application (S-COLA) reviews. This avenue takes advantage of the vast resources available to the SDOs. However, the standards development process can be time-consuming.

- *Topical Reports*: For vendor-specific issues, vendors can submit topical reports, the goal being to resolve a specific licensing issue applicable to that vendor or to preserve vendor proprietary information that could not be protected in an industry consensus standard. When a topical report is approved by the staff, it represents staff approval of the use of that approach that can be relied on in the review of future regulatory submittals. This approach is likely to be quicker than the standards development process. However, the vendor will have to bear the entire resource burden.

Finally, for any process used, there should be transparency for the benefit of all stakeholders to understand the level of protection provided by the innovative designs. Early definitive decisions by the NRC aid transparency. The public benefits not only from knowing what the applicant proposed but also from knowing what the NRC conclusions are. Currently, the NRC is finalizing SERs for many of the designs undergoing DC and combined OL review on a chapter-by-chapter basis. Early decisions on individual chapters of the SER for designs enhance transparency rather than making the public wait years for the entire SER.

## 5.0 CONCLUSIONS

For SMRs of the LWR design, the exemption process is sufficient for licensing.

For non-LWR designs, a technology-neutral framework is needed. Two options for a technology-neutral framework are presented in this paper: the general-safety-standards option and the parity option. It may be impractical and expensive to pursue rulemaking to accommodate each of the areas in which SMRs differ from LWR designs. It may also be impractical to contemplate the issuance of numerous exemptions to approve the ways in which SMRs do not conform to current requirements. It would be more efficient to pursue rulemaking to implement a technology-neutral framework based on the parity change process, where the advantages of SMRs can be compared on an equal footing to those of current designs. In this way, decisions about compliance of SMRs with the regulations can be made in a balanced manner. This process would allow an innovative design to be approved by demonstrating "parity" with current plants, that is, protection equivalent to or greater than that provided by compliance with the current regulations. The change process proposed allows for the provision of a coherent safety case, i.e., a convincing demonstration that the design is safe enough.

## 6.0 RECOMMENDATIONS

1. The ANS President's Special Committee on SMR Generic Licensing Issues (SMR Special Committee) recommends implementing the 10 CFR 50.12 exemption process for special circumstances for DC of LWR-type SMRs.

2. The SMR Special Committee suggests presenting two technology-neutral framework options, as described in this paper, to the NRC and stakeholders: the general-safety-standards option and the parity option, for resolution and selection for a path forward for DC of non-LWR SMRs.

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