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Considerations on the application of IAEA safeguards in SMRs

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1. Introduction

Nuclear power is gaining attention as a carbon-neutral energy source, and Small Modular Reactors (SMRs) are gaining attention worldwide due to their economic and safety aspects. Various types of SMRs are being developed in this trend, and various operating conditions and facility layouts are being proposed. These new approaches can pose new challenges to traditional safeguards. Therefore, we will analyze the advantages and disadvantages of SMRs regarding conventional safeguards approaches and assess their applicability to International Atomic Energy Agency (IAEA) safeguards.

2. IAEA Safeguards Considerations

The IAEA's safeguards approach is to verify the correctness and completeness of the declared nuclear activities in the member states as a supplementary measure that, unlike mandatory safety requirements, does not affect the safety of the nuclear facility. [1] It means that it cannot be presented as a requirement at the design stage and that the basic design layout must be determined before appropriate safeguards can be applied. Therefore, it is impossible to provide specific considerations for SMRs now, but we would like to review the issues that can be foreseen from a general perspective.

The general definition of SMRs refers to reactors of 300 MWe, with iPWR, MSR, SFR, and VHTR as the main types of reactors. Based on this, we summarize the implications for applying IAEA safeguards. [2], [3]

- **Downscaled Reactor**: SMRs have a lower power output than conventional reactors, resulting in a smaller physical footprint and reducing the physical surveillance area for dedicated pathways. On the other hand, the dedicated pathway will likely become more complex to accomplish the same function in a smaller physical space, requiring closer design information verification.

- **Long refueling design concept**: Some reactor types have high burnup due to their long refueling design concepts. While this increases the yield of plutonium itself, it can also have adverse proliferation characteristics, such as degraded plutonium quality and increased fission products. The more extended cooling period before the spent fuel is transported for final disposal or reprocessing can also decrease the frequency of nuclear material inventory change reporting (ICR).

- **Sealed cores**: Sealed cores refer to the sealing of nuclear fuel during reactor fabrication. It can make it challenging to misuse or divert nuclear material because there is no direct access to the fuel. However, additional verification of the reactor fabrication facility and measures are needed to ensure the integrity of the nuclear material from fabrication to operation.

- **High-assay low enriched uranium (HALEU) fuel**: Higher enriched uranium requires closer management because it requires fewer resources and less time to divert to weapons-grade nuclear material.

- **Load-following operation**: Load-following operation can cause defects in burnup by module or fluctuations in the operating cycle, making it difficult to specify the cycle of physical inventory verification (PIV). In particular, since the spent fuel pool is shared, it may be challenging to maintain Continuity of Knowledge (CoK) due to overlapping reload cycles for each module due to load-following operation.

3. Conclusion

As shown above, applying IAEA safeguards to SMRs requires several factors to be considered in advance. While a smaller facility capacity can be assumed to result in a lower stockpile of nuclear material, which would be difficult to proliferate, a more complex facility layout would require additional factors to be considered, such as identifying pathways to detect the diversion of nuclear material and determining the frequency of verification. It is in the interest of the international community and individual states to implement reasonable IAEA safeguards. Therefore, to ensure a more effective and efficient application of safeguards states designing reactors should be able to provide design information about their facilities at the earliest possible stage so that best practices can be established to ensure that safety, security, and safeguards are considered from the design stage.

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