156-2 Safety, Security and Radiation Protection Issues in Advanced Reactors

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Abstract:

Nuclear energy safety focuses on minimizing the risk of radioactive release into the environment. Advanced reactor systems, currently in the design phase, may offer both benefits and drawbacks in safety due to their size, design, and chemical properties of their components (coolant, fuel, moderator). The operational safety of these systems is yet to be established, necessitating testing and demonstration to validate safety claims. Conventional nuclear plants use multiple independent and redundant active safety systems, which rely on electricity or mechanical operations. In contrast, advanced nuclear reactors incorporate passive and inherent safety systems. These passive features include self-regulation of fission rates through negative feedback mechanisms and adequate core cooling in case of electricity loss or failure of active safety systems. Advanced reactor designs may offer both advantages and disadvantages in terms of proliferation risk. Some designs are more resistant to proliferation due to factors like sealed core designs, infrequent refueling, smaller fissile material inventories, and remote monitoring capabilities [1, 2]. However, certain advanced reactor characteristics, such as opaque coolants (e.g., sodium, lead, molten salts), can complicate inspection and monitoring. The IAEA highlights advanced reactor technologies, such as transportable reactors, pebble-bed HTGRs, and molten salt reactors, as particularly challenging to safeguard [3]. Advanced reactors using more highly enriched fuels, such as HALEU (5%-20% fissile isotope enrichment), pose additional nonproliferation challenges [4, 5]. Even small reactors with HALEU could contain enough fissile material for multiple nuclear weapons. Some designs may produce spent fuel with higher concentrations of desirable isotopes for weapons production, increasing the risk of diversion. Some advanced reactors may rely on reprocessing and recycling, making them cost-effective but also creating materials attractive to thieves or countries seeking weapons production. The radioactivity of nuclear waste presents unique waste management and facility contamination challenges [1]. reactors and some unconventional reactors may reduce the prevalence of long-lived waste products, potentially lowering the health risk associated with spent fuel release. However, reprocessing-related liquid radioactive waste has been difficult and expensive to manage. Proponents argue future reprocessing plants will improve waste disposal, but the impact of advanced reactors on the back end of the fuel cycle remains uncertain. Environmental impacts of nuclear energy must also be evaluated, considering air emissions, water discharges, and waste management challenges over the full life cycle [1]. Nuclear power has a limited greenhouse gas footprint and low emissions of conventional air pollutants. Advanced reactors are expected to have similar life-cycle air emissions to existing reactors. Advanced reactors could address cost,

safety, waste management, and fuel supply challenges, allowing nuclear power to play a significant role in reducing global greenhouse gas emissions.

Keywords:

Advanced Reactors, Safety, Security, Radiation Protection