

Fundamentals of Nuclear Safety and Their Application in Design and Operation

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Abstract:

The fundamental objective of nuclear safety is to protect people and the environment from the harmful effects of ionizing radiation. The unique nature of a nuclear reactor requires that three basic safety functions be maintained: control of the reactivity and thereby the power level; cooling of the fuel, not only during operation, but long after shutdown of the fission process; and containment of radioactive material.

Defense-in-depth is the fundamental concept on which nuclear safety in design and operation is based. In design of nuclear reactors, defense-in-depth is implemented by providing multiple physical barriers intended to prevent release of radioactive material into the environment which could cause people to be exposed to excessive radiation levels. In most designs, the physical barriers include the uranium dioxide fuel pellets, the cladding tube, the reactor vessel and associated piping and the containment vessel. Redundant and diverse control and safety systems are provided to avoid off-normal operation and avoid challenges to safety systems that are provided to protect the physical barriers.

Defense-in-depth may also be viewed as a series of levels-of-defense, which include: conservative design and high quality of systems, structures and components; control systems to deal with off-normal conditions and avoid challenges to the safety systems; safety systems to deal with conditions not handled by the control systems so as to avoid conditions that might damage one or more barriers; additional systems and accident management guidelines that can be used to mitigate accidents and reduce the likelihood of a radioactive release; and finally, emergency planning measures.

The success or failure of these measures can be assessed with reference to the Three-mile Island, Chernobyl and Fukushima nuclear power plant accidents.

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