

# 先进反应堆风险指引的堆型评价方法

## 摘要

当前我国先进反应堆技术发展活跃，涉及铅铋快堆、钠冷快堆、高温气冷堆、溶液堆、熔盐堆等不同堆型，采用多样化冷却剂，可用于多种应用场景。一直以来，我国先进反应堆的安全评价主要参考了引进国同堆型的既有内容，未能形成系统化的开发方法。一方面，现行核安全监管框架及评价方法主要以确定论为基础，适用对象为传统水冷反应堆，不能完全反映和适应先进反应堆的设计特征，对核安全监管带来挑战。另一方面，缺少系统性的与先进堆安全特点相适应的评价方法，制约了新技术的发展和工程落地。目前，国家核安全局正在探索与当前核能发展形势相适应的堆型评价方法，针对先进反应堆积极推动风险指引的方法应用。近年来，美国应对新型堆发展的需要，开展了风险指引基于性能（RIPB）的方法论研究，通过许可基准事件选取和评估、构筑物系统和设备安全功能识别、纵深防御充分性评估等工作，采用可预期的方法在概要性问题上达成共识。本报告参考美国 RIPB 的分析方法，结合我国核安全监管形势研究了风险指引的先进反应堆堆型评价方法，包括风险指引的设计基准选取方法，风险指引的构筑物系统和设备安全功能分级，先进堆关键设计承诺研究，并拟就典型先进堆开展案例研究，为我国先进反应堆的堆型评价提供参考。

## 关键词

堆型评价；设计基准；风险指引；基于性能；设计基准事故；许可基准事故；关键设计承诺；先进反应堆。

## Abstract

Currently, the development of advanced reactor technology in China is thriving, encompassing various reactor types such as lead-bismuth fast reactors, sodium-cooled fast reactors, high-temperature gas-cooled reactors, liquid-cooled reactors and molten salt reactors, which utilise diverse coolants and can be applied in a wide range of scenarios. Historically, safety assessments of advanced reactors in China have primarily relied on existing content from the countries of origin for the same reactor types, failing to establish a systematic development methodology. On the one hand, the current nuclear safety regulatory framework and assessment methods are predominantly based on deterministic approaches, designed for conventional water-cooled reactors; consequently, they cannot fully reflect or adapt to the design characteristics of advanced reactors, posing challenges for nuclear safety regulation. On the other hand, the absence of systematic assessment methods tailored to the safety characteristics of advanced reactors has constrained the development of new technologies and their engineering implementation. Currently, the National Nuclear Safety Administration is exploring reactor evaluation methods suited to the current nuclear energy development landscape, and is actively promoting the application of risk-informed approaches for advanced reactors. In recent years, in response to the development of new reactor types, the United States has conducted methodological research on Risk-Informed Performance-Based (RIPB) approaches. Through the selection and assessment of licence-defining events, the identification of safety functions in building systems and equipment, and the evaluation of the adequacy of defence-in-depth, a consensus has been reached on overarching issues using a predictable methodology. This research report draws upon the analytical methods of the US RIPB and, in light of China's nuclear safety regulatory context, examines risk-informed evaluation methods for advanced reactor designs. This includes the selection of design bases for risk-informed approaches, the classification of safety functions for building systems and equipment, and the study of key design commitments for advanced reactors. Furthermore, the report proposes case studies on typical advanced reactors to provide a reference for the evaluation of advanced reactor designs in China.

## Keywords

Reactor Design Review; Design Basis; Risk-informed; Performance-based; Design Basis Accident; Licensing Basis Accident; Key Design Commitments; Advanced Reactors.

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