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# 先进小型一体化全自然循环压水堆关键安全特性整体性能试验研究


## 摘要

针对国家电投集团开发的先进小型一体化全自然循环压水堆（供热堆），为满足安全审评对整体性能试验的验证要求，本文介绍基于多级双层比例分析方法（H2TS）设计建造的整体性能试验台架及典型工况试验。该台架在几何布置、系统配置及专设安全设施方面与原型堆保持高度一致，能够准确表征反应堆的热工水力现象。本文选取了典型设计基准工况开展试验研究。结果表明：在稳压器顶部破口（LOCA）工况下，非能动应急堆芯冷却系统（JNG）能够按预设逻辑自动触发，自动卸压与直接注射的协同动作，确保了堆芯在整个事故进程中处于淹没状态，有效缓解了事故后果；在丧失三回路热阱（非 LOCA）工况下，非能动二次侧余热排出系统（NCR）能够及时投入并建立稳定的自然循环，有效导出堆芯衰变热，防止系统超压。试验数据充分验证了供热堆专设安全系统容量配置的充裕性及事故缓解逻辑的正确性，为该类反应堆的安全审评提供了关键的试验依据。



## 关键词

一体化全自然循环；小堆；非能动安全；整体性能试验；安全特性验证



## Abstract

This paper presents an integral effect test facility designed and constructed based on the Hierarchical Two-Tiered Scaling (H2TS) methodology to meet the verification requirements for the integral performance test of an advanced small modular integral pressurized water reactor (heating reactor) developed by SPIC. The test facility maintains high fidelity to the prototype in geometric configuration, system layout, and engineered safety features, enabling accurate simulation of its key thermal-hydraulic phenomena. Experimental studies on typical design-basis conditions were carried out. The results demonstrate that: (1) For a pressurizer top LOCA, the passive Emergency Core Cooling System (JNG) is automatically activated as designed; the coordinated operation of the Automatic Depressurization System and the Direct Vessel Injection system ensures core submergence throughout the transient, effectively mitigating the accident consequences. (2) For a loss of tertiary heat sink accident (non-LOCA), the Passive Residual Heat Removal system (PRHRS) engages promptly and establishes stable natural circulation, successfully removing core decay heat and preventing system overpressure. The test data fully validate the sufficient capacity of the reactor's engineered safety systems and the correctness of the accident mitigation logic, providing essential experimental evidence for the safety review of this reactor type.



## Keywords

Integral full natural circulation; Small Modular Reactor (SMR); Passive safety; Integral effect test; Safety characteristic validation



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