# THE PERFORMANCE AND SAFETY ANALYSIS OF PASSIVE SAFETY FEATURES IN APR1000

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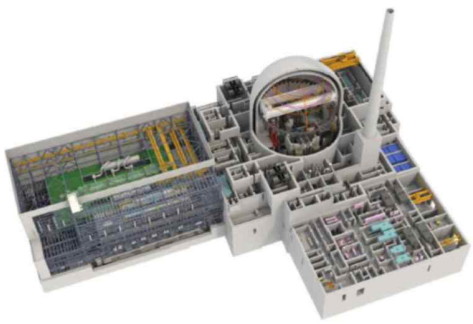
## EXTENDED ABSTRACT

APR1000 is a Generation III+ reactor with thermal output of 2,825 MWt, electrical output of 1,000 MWe, and two steam generators. The design life of APR1000 is 60 years and its safety and economics have been significantly improved based on experience and proven technologies of the OPR1000 and APR1400. Safety systems used for Design Basis Accident (DBA) are designed to have N+2 redundancy, in which mechanical, electrical and I&C systems are comprised of fully independent four trains as shown in figure 1. The Passive Auxiliary Feedwater System (PAFS), which does not use electrical power supply, enhances plant safety considerably. APR1000 provides Diverse Safety Features that are used to reach and maintain safe shutdown state in the event of Design Extension Conditions (DEC) without core melt, where the DBA safety systems are not available. They include the Emergency Boration System (EBS), diverse residual heat removal function of Diverse Containment Spray System (DCSS), Diverse Spent Fuel Pool Cooling System (DSFPCS) and Alternate AC Diesel Generator (AAC DG). The Passive Auxiliary Feedwater System (PAFS) has been designed to replace the active auxiliary feedwater system enabling residual heat removal without external power supply. This paper presents the safety and performance analysis results of the PAFS using the SPACE code.



**APR1000 Major Parameters**

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|---|---|---|
| GENERAL PLANT DATA | Gross Power Output | 1,050 MWe |
| | Thermal Power | 2,825 MWth |
| | Design Lifetime | 60 years |
| | Seismic Design Basis | DBE 0.3g |
| REACTOR CORE | Active Core Length | 3.81 m |
| | Core Diameter | 3.124 m |
| | Average Heat Flux at 100% Power | 589.1 kW/m2 |
| | Number of Fuel Assemblies | 177, 16×16 |
| | Fuel Cycle Length | 12 to 24 months |
| REACTOR COOLANT SYSTEM | Number of Loops | 2 |
| | Operating Pressure | 15.5 Mpa |
| | Inlet Temperature | 295.8℃ |
| | Outlet Temperature | 327.3℃ |

**FIGURE 1. APR1000 Overview and Major Parameters**

The Passive Auxiliary Feedwater System (PAFS) of the APR1000 is an engineered safety system designed to perform critical safety functions by ensuring adequate condensate supply to the steam generators (SGs) under all accident conditions that require cooling of the Reactor Coolant System (RCS). Utilizing the SGs, the PAFS safely cools down the plant to conditions where shutdown cooling is achievable, thereby preventing core damage. The PAFS is composed of two independent trains per SG, with each train incorporating a Passive Condensation Heat Exchanger (PCHX) capable of removing 50% of the required decay heat [1] as shown in figure 2.

Each train consists of the following components: 1) A steam supply line branching off from the main steam line upstream of the Main Steam Isolation Valve (MSIV), which delivers steam to the PCHX, The PCHX, which condenses the supplied steam, 2) A Passive Condensation Cooling Tank (PCCT), which condenses steam through the PCHX tubes, A passive auxiliary feedwater supply line that returns the recovered condensate from the PCHX to the SG economizer nozzles, 3) Isolation and check valves, which isolate the system under normal conditions and actuate during accident conditions.

During an accident, the PAFS operates automatically upon receiving the Passive Auxiliary Feedwater Actuation Signal (PAFAS), which opens the system's isolation valves. The system is designed to passively supply sufficient condensate to the SGs to achieve a safe plant cooldown to shutdown conditions. The PAFS operates entirely through natural driving forces such as gravity, steam condensation, and fluid density differences.

The safety analysis of the APR1000, equipped with PAFS replacing the active auxiliary feedwater system, is performed using the SPACE code (version 3.22). To ensure the credibility of safety analysis results related to auxiliary feedwater injection, it is essential to understand both the PAFS input model and the associated analysis outcomes. The key aspects of the performance and safety analysis of PAFS consists of: 1) Description of the PAFS, 2) Assessment of the SPACE code's prediction capabilities for key thermal-hydraulic phenomena associated with the PAFS, 3) Development of the PAFS input model, 4) Performance analysis results of the PAFS.

The results of the SPACE code evaluation for major thermal-hydraulic phenomena in the PAFS are summarized as follows: 1) SPACE can simulate major PAFS phenomena such as single-phase and two-phase flow pressure drops, natural circulation, and phase-change heat transfer, 2) SPACE shows good predictive capability for single-phase pressure drops and natural circulation flow, 3) For two-phase flow regions, SPACE tends to underestimate pressure drop, which may lead to an overprediction of natural circulation flow rate, 4) The default heat transfer model in SPACE tends to underpredict heat transfer within the PCHX tubes, 5) SPACE successfully replicates the key thermal-hydraulic behaviors observed in the ATLAS integral effect tests related to PAFS [2].

Based on the understanding of key thermal-hydraulic phenomena and SPACE modeling methods, the PAFS input model for APR1000 was developed and performance analysis was conducted. The results confirmed that SPACE can physically and plausibly predict the key behaviors expected in PAFS operation and that the calculation results are stable [3]. Therefore, the developed PAFS input model is deemed suitable for safety analysis and is expected to provide physically reasonable results.

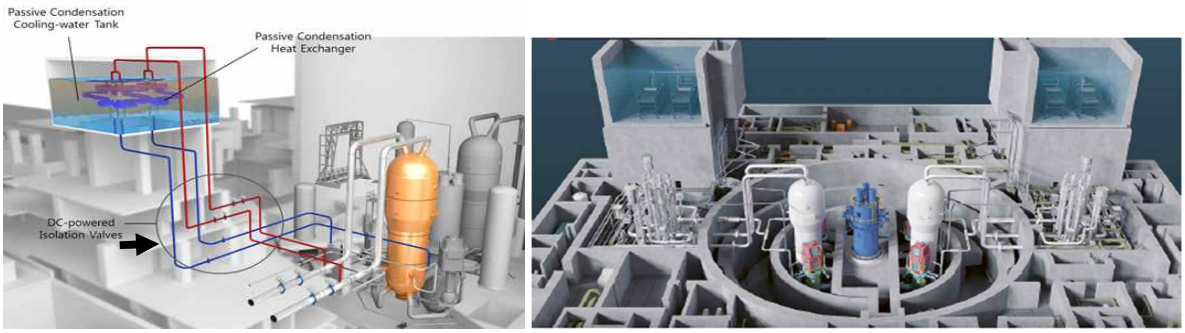


**FIGURE 2. APR1000 Passive Auxiliary Feedwater System**

## REFERENCES

[1] Bae, B. B., Yun, B. J., Kim, S., and Kang, K. H., Design of condensation heat exchanger for the PAFS (Passive Auxiliary Feedwater System) of APR+ (Advanced Power Reactor Plus), Annals of Nuclear Energy, Vol. 46, pp. 134-143, 2012.
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[3] Kang, K. H., Kim, S., Bae, B. B., Cho, Y. J., Park, Y. S., and Yun, B. J., SEPARATE AND INTEGRAL EFFECT TESTS FOR VALIDATION OF COOLING AND OPERATIONAL PERFORMANCE OF THE APR+ PASSIVE AUXILIARY FEEDWATER SYSTEM, Nuclear Engineering and Technology, Vol. 44, pp. 597-610, 2012.