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High temperature design and evaluation of forced draft sodium-to-air heat exchanger in PGSFR

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In PGSFR (prototype-gen IV sodium-cooled fast reactor), two kinds of DHRSs (decay heat removal systems) are employed for emergency decay heat removal during a loss of normal heat sink accident, which are ADHRS (active decay heat removal system) and PDHRS (the passive decay heat removal system). The ADHRS is a safety-grade active system, which is comprised of two independent loops with a single sodium-to-sodium decay heat exchanger (DHX) immersed in cold pool region and a single forced-draft sodium-to-air heat exchanger (FHX) located in upper region of the reactor building. The total heat removal capacity of the DHRS is 10 MWt which amounts to about 2.5% of the rated core thermal power. The DHRS is capable of cooling the plant from an initial temperature corresponding to any power operation condition to the safe shutdown condition within 72 hours after reactor shutdown with a single failure. The FHX employed in the ADHRS is a shell-and-tube type counter-current flow heat exchanger with M-shaped finned-tube arrangement. Liquid sodium flows inside the heat transfer tubes and atmospheric air flows over the finned tubes. During normal plant operation, small amount of heat loss through the FHX is permitted to prevent potential flow reversal or stagnation in each decay heat removal sodium loop. After the reactor shutdown, heat removal rate increases by opening dampers located in air flow paths of FHXs, and then the heat transferred to the decay heat removal system is finally dissipated into the atmosphere. In this study, high temperature design and creep-fatigue damage evaluation for a FHX were conducted. A creep-fatigue damage evaluation was performed according to the elevated temperature design codes of ASME B&PV Section III Division 5 based on a full 3D finite element analysis. The integrity of the heat exchangers under creep-fatigue loading was confirmed.

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