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Leak-Before-Break Design of Double-Walled Once-Through Steam Generators for Lead Cooled Fast Reactor

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Among the various types of liquid metal cooled fast reactor, lead cooled fast reactor (LFR) can take a closed fuel cycle to manage fertile fuel and actinide efficiently. LFR can adapt an External Boiling Bayonet Steam Generator (EBBSG) system instead of conventional once-through high pressure steam generator. LFR with the EBBSG has advantages in terms of thermal efficiency and safety during operation. The EBSSG designs have proven extensive operating experiences in submarine reactors of the Former Soviet Union. However, their complex tube geometries invite life-limiting disadvantages ranging from vibration-led fatigue, oxide particles sedimentation and increased resistance to natural circulation under accident conditions.
The EBBSG system has thermal vibration issues at the nozzle because of a huge heat exchanger inside once-through steam boiler which consists of additional steam blowers. Furthermore, this vibration can lower the heat transfer efficiency of heat exchanger due to the adhesion phenomenon of impurities from lead coolant. And then, fatigue failure as well as environmental corrosion may occur at the shell side of heat exchanger, which leads the coolant leakage accident. To assure the overall performance of steam generator, those structural material degradation issues on the thermal vibration should be solved.
In this paper, we present innovative design concepts for durable, maintainable and accident-tolerant double-walled once-through steam generators (DWOTSG) that can fulfill requirements for non-refueling and hermetically-sealed 40 years life micro-modular LFR: Micro-Uranus. The newly designed tube for steam generator is consisted of double walled layers. In order to assure Leak-Before-Break (LBB), the inter-tubular gap is filled with engineered materials for leak detection and conductivity enhancement. Tube materials are also designed to assure prolonged corrosion resistance and oxide deposition control on heavy-liquid metal side. Exceptional corrosion resistance over 40 year-life can be delivered by Functionally Graded Composite (FGC) tubes with substrate made of internationally certified fast reactor fuel cladding materials. Oxide deposition and thermal degradation can be controlled by advanced flow channel structure and maintenance designs. The LBB characteristics, corrosion resistance, thermal-hydraulic performance of the innovative designs will be presented using fracture mechanics, oxidation and heat transfer models.

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