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## Highly Compact Steam Generators for Improved Economics of Small Modular Reactors

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### **ABSTRACT:**

The cost of Nuclear Power Plants (NPPs) has been the biggest challenge for new applications of nuclear energy. Small Modular Reactors (SMRs) have the opportunity to provide nuclear energy at a much lower capital cost than a traditional GWe plant. However, to keep the cost per kWh as low as possible innovation is needed to minimize the size of the primary to secondary heat transfer system, especially when the steam generator is placed inside the Reactor Pressure Vessel (RPV) in an integral pressurized water reactor (iPWR), which is the highest cost component. Utilizing a compact plate-type steam generator inside the RPV can reduce the cost of SMRs and help facilitate their deployment. Compact steam generator (CSGs) have broader applications beyond iPWR. For example, one of the biggest challenges to Sodium Fast Reactors (SFRs) is avoiding the water to sodium reaction that could be induced from leakage of the secondary side SG tubes. The CSG could remove the need for an intermediate loop. Designing a CSG using available manufacturing techniques used for compact heat exchangers (CHE) is a highly attractive development path for integral SMR applications. CHEs have historically been considered as a heat exchanger for various advanced reactor designs with the sole focus on single phase flow for development of codes and standards. The size of these channels is in a range that is below that of traditional heat exchangers ( $> 5$  mm) and above the size of the micro channels typically used for electronics cooling ( $< 0.5$  mm). This intermediate “mini” channel range has not been well explored for steam generation and needs better data for flow regime maps and resulting heat transfer coefficients. The immaturity of the simulation tools is one of the limiting factors in the development and adoption of the CSG technology.

The proposed project will design and build a compact steam generator test section that can be easily modified for different flow paths and geometries and an existing loop will be modified to accept the test section. The design will be informed by Computational Fluid Dynamics (CFD) simulations to determine critical characteristics of the test section. The test section will allow the determination of the flow regime via high speed video, the heat transfer coefficient measurement via thermocouples and infrared thermography, as well as traditional measurements such as flow rate, temperatures, and pressures. Various flows, temperatures, and pressures will be tested to make up the experimental matrix as well as investigating performance problems and their solutions such as channel plugging, fouling, cleaning methods, and settling zones to prevent fouling. The results of the experiments will be used to develop flow regime maps and associated heat transfer coefficient models to inform modeling efforts and CFD. The resulting models will be used to develop a conceptual optimized CSG system that could be deployed in SMRs.