# Development of an Evaporator-Condenser Heat Exchanger for the Super-Long Gravity Heat Pipe Geothermal Systems

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## Abstract

A shell-and-tube heat exchanger is widely used in many industrial areas due to its versatility and reliability. It serves as a critical interface between the heat pump and the recently proposed super-long gravity heat pipe (SLGHP) system, designed for deep geothermal heat extraction. By enabling substantial heat transport from the underground source, the SLGHP system offers notable benefits in effectiveness and economic viability; however, the limited capacity of the heat exchanger to transmit this energy constrains the heat pump's performance, thereby reducing overall system efficiency. To overcome this challenge, a two-phase flow heat exchanger is proposed, facilitating condensation on the shell side coupled with evaporation on the tube side, thereby enabling an integrated perspective on phase-change heat transfer. This study develops a model to examine the thermal performance of a coupled evaporation/condensation mechanism, which is validated against experimental data and shows good agreement. The results demonstrate that increasing the shell side mass flow rate enhances heat absorption in the heat pipe evaporator and strengthens heat transfer to the tube-side fluid, thereby reducing the temperature difference across the heat exchanger. Low tube-side mass flow rates result in a stratified flow with partial dry-out and increased evaporation; however, the associated high tube side thermal resistance limits the shell-side condensation. In contrast, higher tube-side mass flow rates promote annular flow, markedly reducing thermal resistance and enhancing condensation. Further increases in tube-side mass flow rate transition the flow into a bubble regime, providing only marginal gains. A lower tube count increases flow rate within tube side, significantly boosting both condensation and evaporation. Conversely, increasing the tube count decreases the mass flow rate per tube, causing tube-side thermal resistance to dominate, which suppresses the evaporation rate and constrains heat transfer. These findings underscore the need for a delicate balance of structural and operational conditions to optimize shell-side condensation in conjunction with tube-side evaporation, thereby enhancing the overall thermal performance of the SLGHP system.

## Keywords

Geothermal Energy, Super-long Gravity Heat Pipe, Shell-and-tube Heat Exchanger, Condensation; Evaporation, Thermal Performance