Multi-stage Membrane Distillation Process
Technology #15901

Applications

This multi-stage vacuum membrane distillation technology has applications in small-scale or off-grid desalination, where it delivers performance and efficiency comparable to existing large-scale systems at lower capital cost.

Problem Addressed

In vacuum membrane distillation (VMD), a saline liquid stream is vaporized and driven across a hydrophobic porous membrane by lowering the pressure on the vapor side of the membrane. The desalinated vapor is condensed and cooled to recover the latent heat of vaporization. VMD systems are attractive because their relatively low operating temperatures and pressures result in lower capital cost. However, existing VMD systems suffer from poor thermal efficiency (Gained Output Ratio, \(\text{GOR} < 1\)) as drawing a higher vacuum on the vapor side of the membrane to increase throughput results in a lower condensation temperature and lower energy recovery effectiveness. Multi-stage flash (MSF) desalination systems offer superior thermal efficiency (3 < \(\text{GOR} < 7\)), but the high temperatures and pressures required for these systems limit their feasibility in small-scale or off-grid applications.

The novel desalination cycle described in this invention addresses these problems by achieving throughput and thermal efficiency comparable to MSF systems while retaining the capital cost advantage of VMD systems.

Technology

This invention overcomes the tradeoff between throughput and thermal efficiency inherent in single-stage VMD systems by cascading multiple VMD modules each operating at progressively lower pressures. At each stage, heated feed water is vaporized and driven through a gas-permeable membrane by a vacuum drawn on the vapor side of the membrane. The hot product water is passed through a condenser and a permeate cooler where energy is transferred to cold incoming feed water. Liquid feed water remaining in the first vaporization vessel is then transferred to the next stage where further vaporization is induced by the lower vapor-side pressure and the process is repeated. Systems can be built with arbitrary numbers of stages, with more numerous stages associated with better thermal efficiency and increased equipment cost.

This multi-stage VMD system achieves high throughput since each module produces desalinated water in parallel. Additionally, thermal efficiency is improved by vaporizing as much water as possible at early, low-vacuum, stages before proceeding to later, high-vacuum stages. This allows more heat to be recovered as incoming feed water absorbs energy from progressively hotter product water as its own temperature rises.
Advantages

- Requires smaller, lower-pressure, and cheaper containment vessels compared to MSF systems
- Amenable to scaling down for low volume operations
- Compatible with low-temperature heat sources such as unconcentrated solar energy
- Lower operating temperatures reduce risk of fouling on membrane and heat exchanger surfaces

Categories For This Invention:

- Water Treatment
- Desalination

Intellectual Property:

Multi-stage membrane distillation process
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