Loop Thermosyphon Enhanced Solar Collector

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Solar availability for desalination

Global Horizontal Irradiation (GHI)

Solar Irradiation

Water Stress
ACT, collaborating with UMD, is developing an innovative, low-cost Loop Thermosyphon Solar Collection (LTSC) system.

The overall project goal: to develop a LTSC system that efficiently collect and convert up to 1.5 kW/m² solar radiation to generate steam from brackish water at an overall efficiency of >80%, with an installation cost of less than $30/m².

System components:
- Solar concentrator
- Evacuated glass tube
- Volumetric absorbing nanofluid
- Loop thermosyphon
- Steam generator
Technical Innovation

- Graphene-oxide based nanofluid
  - Volumetric solar absorbing
  - Local heating of working fluid
  - Reliable two-phase durability with no surfactant
- Transparent evacuated glass tube
  - No back surface absorbing coating
  - Decreased surface radiation and coating cost
  - No risk of coating degradation
  - No risk of nanofluid degradation at hot surface
  - Current low-cost evacuated tube and coating technologies including anti-reflection and low emission coatings will be leveraged
- High performance loop thermosyphon system
  - High heat flux limit
  - Stable two-phase nanofluid circulation
  - Passive operation with no solid moving parts
  - Low maintenance with no operation cost
- Overall high solar-to-thermal energy conversion rate with low
Technical Approach

Nanofluid
- Nanofluid Identification
- Nanofluid Synthesis & Characterization
- Nanofluid Reliability Tests

Modeling
- System Modeling Framework
- System Modeling Development

Components
- Inclined Loop Thermosyphon Evaluation
- Evacuated Glass Tube Development
- Structure Cycling Tests

Prototype
- Heat Source & Sink Tests
- Subscale Prototype
- Full-scale Prototype

Market
- Stakeholder Identification
- Stakeholder Engagement
- Market Identification
- Market Strategy Development
Loop thermosyphon modeling

Pressure balance: \[ \sum \Delta P_{\text{friction}} + \sum \Delta P_{\text{gravitational}} = 0 \]

Mass balance: \[ \dot{m}_{\text{tot}} = \sum \dot{m}_{\text{vapor}} + \sum \dot{m}_{\text{liquid}} \]

Input Power: \[ \text{Power} = \dot{m}_{\text{tot}} h_{fg} (x_7-x_2) \]
Nanofluid synthesis

• Literature review: graphene/GO nanofluids are suitable working fluids in the loop thermosyphon system
  • Metal/ceramic nanofluids are instable without surfactant
  • Graphene/GO nanofluids have high thermal conductivity, high solar absorbance, high stability, and moderate viscosity increase
• Partially-reduced graphene oxide aqueous nanofluids will be used as the bulk solar absorbing working fluid
  • Absorbing efficiency near 100% over solar wavelength
  • Non-surfactant nanofluid for two-phase stability
• Volumetric boiling of the working fluids
  • Preventing nanoparticle precipitation and agglomeration on a hot surface
  • In-situ boiling of working fluid on the graphene oxide – water interface minimizes thermal resistance (large heat transfer area)
Summary

• ACT and UMD are developing a Thermosyphon Solar Collection system to provide low-cost solar thermal energy for desalination.
  • Low-cost, reliable passive loop thermosyphon operation
  • Volumetric solar conversion by nanofluid
  • High solar-to-thermal efficiency with low thermal resistance and exergy loss
• Budget: $1.5M federal + $375k cost share
  • 10/01/2018 – 09/30/2021
• Impact
  • Reduced cost of solar heat for desalination etc.
  • Broader freshwater resources from brackish water at acceptable cost
  • Passive loop thermosyphon technology for other heat transfer applications
Questions?