Short communication:
NIPES-Journal of Science and Technology Research 1(10) 2024 pp 1-11. ISSN-2682-5821

NIPES

Journal of Science and Technology Research

Journal homepage: www.nipesjournals.org.ng

Advancements in Heat Transfer Fluids for Concentrated Solar Power Systems: A Brief Review

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Abstract

This review examines recent developments in heat transfer fluids (HTFs) for concentrated solar power (CSP) systems, focusing on molten salts, synthetic oils, and nanofluids. We discuss their thermophysical properties, applications, and challenges, highlighting the potential of novel HTF formulations to enhance CSP efficiency and sustainability.

Keywords: Concentrated Solar Power (CSP), Heat Transfer Fluids, Nitrate salts, molten salt

https://doi.org/10.5281/zenodo.14020385

Introduction

Concentrated Solar Power (CSP) technology has emerged as a promising renewable energy solution, capable of providing steady, on-demand power. Central to CSP efficiency is the selection of appropriate heat transfer fluids (HTFs), which are responsible for transporting and storing thermal energy. This review examines the most common HTFs used in CSP applications, their properties, and emerging trends in the field [1-3].

Types of Heat Transfer Fluids:

1. Molten Salts: Widely used for high-temperature applications (>250°C), offering high thermal stability and specific heat capacity.

2. Synthetic Oils: Suitable for moderate temperatures (150-400°C), with lower melting points and viscosity.

3. Nanofluids: Emerging class of HTFs with enhanced thermal conductivity and heat capacity.

4. Gaseous Fluids: Used in specific high-temperature applications, offering low cost and environmental safety.

Table 1: Comparison of Common Heat Transfer Fluids in CSP Systems

Property	Molten Salts	Synthetic Oils	Nanofluids
Operating Temperature Range (°C)	**250-600**	**150-400**	**20-600***
Specific Heat Capacity (kJ/kg·K)	**1.5-2.5**	**1.5-2.2**	**2.0-3.0***
Thermal Conductivity (W/m·K)	**0.5-0.8**	**0.1-0.3**	**0.3-1.0***
Density (kg/m³)	**1700-2100**	**750-1000**	**800-2200***
Viscosity (mPa·s) at 300°C	**3-5**	**0.2-0.5**	**0.3-2.0***

***Values for nanofluids can vary widely depending on the base fluid and nanoparticle composition.**

Thermophysical Properties and Performance:

The effectiveness of HTFs in CSP systems is largely determined by their thermophysical properties, including specific heat capacity, thermal conductivity, density, viscosity, and thermal stability. These properties influence the fluid's ability to store and transfer heat efficiently.

Molten salts, particularly ternary and quaternary mixtures, exhibit high specific heat capacities and thermal stability, making them effective for thermal energy storage. However, their high melting points (around 220°C for Solar Salt) pose freezing risks.

Synthetic oils offer lower melting points and viscosity, suitable for parabolic trough CSP plants. Their main limitation is thermal stability, decomposing at temperatures above 400°C.Nanofluids show promise in enhancing thermal conductivity and heat capacity, potentially improving overall heat transfer performance. However, challenges remain in maintaining long-term stability and managing increased viscosity [4-6].

Emerging Trends and Challenges:

1. Hybrid HTFs: Combining traditional HTFs with additives to optimize thermal performance.
2. Supercritical CO_2 Cycles: Exploring high-efficiency HTFs for high-temperature applications.

3. Advanced Nanofluids: Developing novel nanoparticle materials and stable formulations.

Challenges include thermal stability at high temperatures, corrosion and material compatibility, high melting points, economic viability, and environmental impact. Figure 1 shows the comparison of the heat transfer fluid properties [4-10].

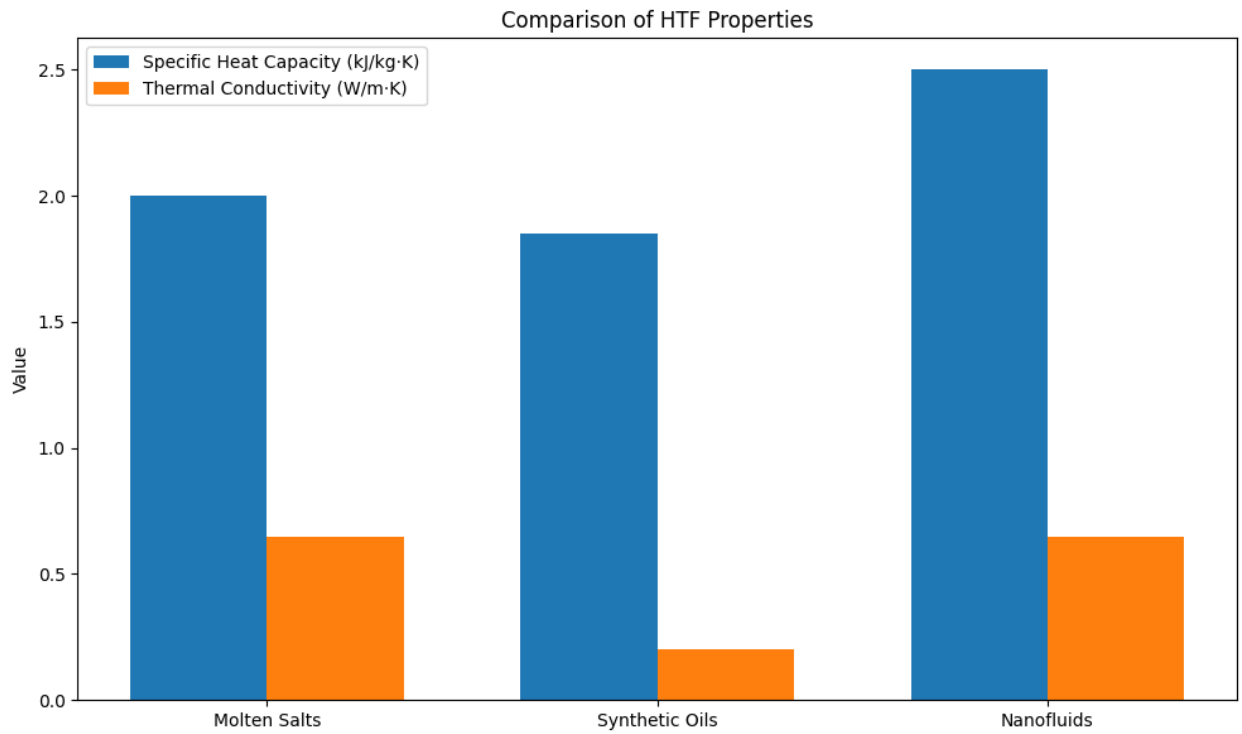

Figure1: Comparison of HTF properties

Conclusion

Advancements in HTF technology are crucial for enhancing the efficiency and economic viability of CSP systems. While molten salts and synthetic oils remain the most widely used HTFs, emerging technologies like nanofluids and hybrid formulations show promise for future applications. Addressing challenges in thermal stability, corrosion resistance, and environmental impact will be key to optimizing CSP performance and supporting the transition to sustainable energy solutions.

References

[1] Alva, Guruprasad, et al. "Thermal energy storage materials and systems for solar energy applications." *Renewable and Sustainable Energy Reviews* 68 (2017): 693-706.

[2] Garg, Hari Prakash, Subhash C. Mullick, and Vijay K. Bhargava. *Solar thermal energy storage*. Springer Science & Business Media, 2012.

[3] Egware, Henry Okechukwu, and Collins Chike Kwasi-Effah. "A novel empirical model for predicting the carbon dioxide emission of a gas turbine power plant." *Heliyon* 9.3 (2023).

[4] Kwasi-Effah, Collins C., et al. "Characterization and comparison of the thermophysical property of ternary and quaternary salt mixtures for solar thermal power plant applications." *Results in Engineering* 16 (2022): 100721.

[5] Kwasi-Effah, Collins C., et al. "A novel empirical model for predicting the heat accumulation of a thermal energy storage medium for solar thermal applications." *Journal of Energy Storage* 56 (2022): 105969.

[6] Kwasi-Effah, Collins C., et al. "Development and characterization of a quaternary nitrate based molten salt heat transfer fluid for concentrated solar power plant." *Heliyon* 9.5 (2023).

[7] Kwasi-Effah, Collins Chike, et al. "Enhancing thermal conductivity of novel ternary nitrate salt mixtures for thermal energy storage (TES) fluid." *Progress in Engineering Science* 1.4 (2024): 100020.

[8] Sarbu, Ioan, and Calin Sebarchievici. "A comprehensive review of thermal energy storage." *Sustainability* 10.1 (2018): 191.

[9] Kwasi-Effah, Collins Chike, et al. "Recent progress in the development of thermal energy storage mediums for solar applications." *J. Eng. Dev* 15.1 (2023): 146-170.

[10] Shukla, Anant, D. Buddhi, and R. L. Sawhney. "Solar water heaters with phase change material thermal energy storage medium: A review." *Renewable and Sustainable Energy Reviews* 13.8 (2009): 2119-2125.