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Butane heat pipes for stagnation temperature reduction of solar thermal collectors

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Abstract

Heat pipes in solar thermal collectors enable to reduce the temperature loads in the solar circuit during stagnation periods by exploiting their dry out limit. Typically water, pentane or acetone are used as heat transfer media in collector heat pipes. Butane is very suitable to reach a high temperature gradient of the dry out even if the maximum temperature in the fluid circuit should be designed to 120°C or below. The paper presents experimental results with butane heat pipes that operate up to a maximum temperature of 120°C with a high temperature gradient in the dry-out region. This ensures that the collector performance in the operating range (typically up to 100°C) is not affected negatively by the dry-out. Different approaches to increase the thermal conductance of butane heat pipes by enhancing the inner surface of the condenser or of both, the condenser and the evaporator are experimentally assessed and discussed. Measurement results report an increase of the heat pipes' thermal conductance from 3 W/K (standard geometry) to 23 W/K.

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Keywords: heat pipe, stagnation temperature, cost reduction, butane, flat plate collector, evacuated tube collector

1. Introduction

Heat pipes in solar thermal collectors are state-of-the-art devices for solar heat transfer from the absorber plate to the heat transfer medium inside the collector. This technology is established for evacuated tube collectors, for flat

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plate collectors it has up to now only been demonstrated in research projects (e.g. [1]).

As the heat pipe is an additional component in the heat transfer path between the absorber plate and the collector fluid in the manifold (see Fig. 1), a high thermal conductance of the heat pipe is essential to achieve a high collector efficiency. Further the heat pipe decouples the absorber plate from the fluid circuit. If the heat transfer by two-phase flow inside the heat pipe is stopped, beginning from a certain temperature, the maximum temperature in the solar fluid can be limited to reduce thermal loads. The deactivation of the heat transfer process can be achieved by employing the dry-out limit of heat pipes. With this approach vapour formation in the solar circuit can be completely avoided which is essential to reduce costs of solar thermal systems by simplified and more reliable solar circuits.

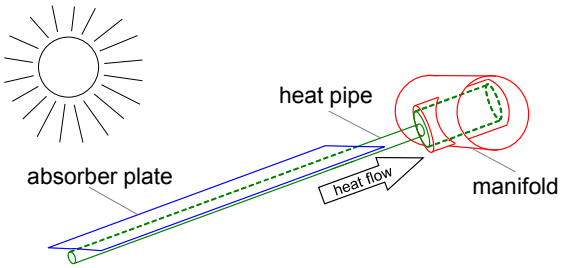

Fig. 1. Schematical drawing of a solar thermal collector configuration with a heat pipe as an additional component between the absorber plate and the manifold

2. Butane as heat transfer medium in heat pipes

The thermodynamic properties of the heat transfer medium in the heat pipe strongly influence the thermal conductance and the dry-out temperature. State-of-the-art media used in collector heat pipes are water or organic media like ketones (e.g. acetone) or alkanes (e.g. hexane) [2].

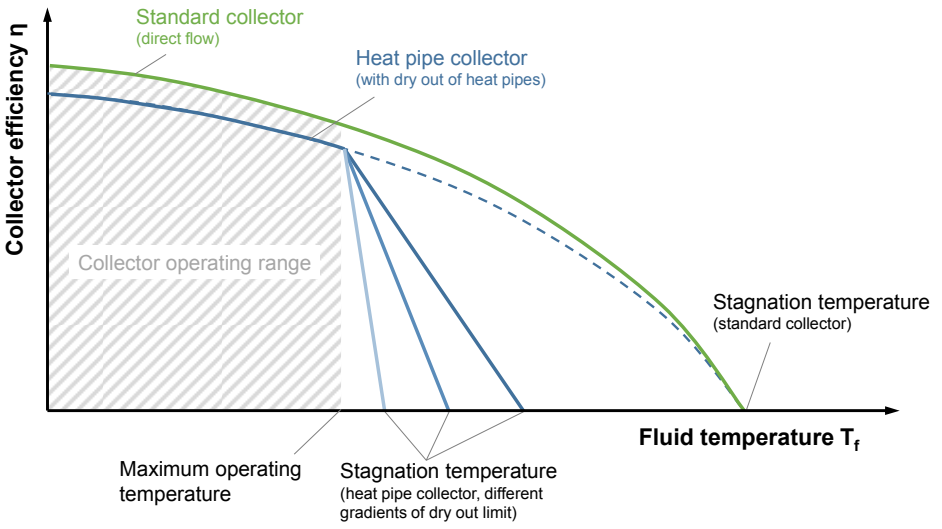

Fig. 2. Stagnation temperature (defined as the maximum fluid temperature without internal heat removal) according to the collector efficiency curve for a standard collector (direct flow) and a heat pipe collector with different gradients of the deactivation due to the dry out limit (schematic illustration).