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Effects of measurement conditions on operating limits of solar horizontal heat pipes

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Abstract

In this work operating limit measurements are presented for one self-fabricated and one commercial solar heat pipe at horizontal and small inclination angles. While for the self-fabricated test sample heat transfer is limited by entrainment, dry-out limit is observed for the commercial solar heat pipe. Operating limit measurements of the commercial solar heat pipe show good reproducibility, whereas the detected operating limit of the self-fabricated heat pipe varies drastically. When tested at slight inclination, high temperature oscillations indicating geyser boiling effects are observed for the commercial test sample. Finally, operating limit definitions given by the literature are discussed regarding their applicability for solar thermal applications.

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Keywords: heat pipe; two-phase thermosyphon; solar collector; horizontal operation; operating limits; heat transfer limits

1. Introduction

1.1. Motivation

High flexibility in architectural design is the key for a broad application and acceptance of solar thermal façade integration. Solar collectors which use heat pipes or closed two-phase thermosyphons to transport the energy from the absorber to the manifold are an interesting option for this purpose. The separation of the hydraulic circuit of the

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Nomenclature

Q	power (W)	*ev*	evaporator
T	temperature (°C)	*elec*	electric
		pool	pool boiling region
Subscripts		*film*	film boiling region
ad	adiabatic		

absorber and the manifold constitutes the basis for the development of highly modular and flexible collector concepts. Especially the so called "dry connection" of the heat pipe or two-phase thermosyphon to the manifold allows for modular collector concepts leading to high architectural flexibility in design and thermal output. Moreover, it is expected that with those modular collector concepts also production, installation and maintenance costs can be reduced. Two examples of architecturally highly integrated heat pipe solar façade collector concepts being developed at Fraunhofer ISE are presented in Fig. 1.

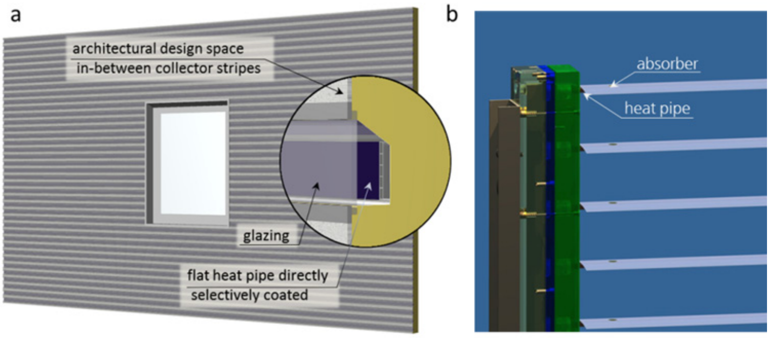

Fig. 1. Modular solar façade collector concepts using heat pipes: (a) stripe collector; (b) venetian blind.

State of the art solar collectors operate with closed two-phase thermosyphons. While heat pipes use capillary forces to recirculate the condensate to the evaporator, closed two-phase thermosyphons resort to gravitational forces [1,2][1]. Therefore, state-of-the-art standard collectors only operate successfully at a specific minimum inclination. As a consequence, the advantage of "high modularity" is opposed to the disadvantage of "orientation restriction" of the two-phase thermosyphon. However, a reliable operation at various – also horizontal – inclination angles is significant to achieve high design freedom and thus acceptance of solar façade integration by architects.

Before including wick structures, the simplest option to enlarge the operating envelope of closed two-phase thermosyphons towards horizontal is the "overfilling" of the thermosyphon using higher fill rates [3]. While "overfilling" increases the dry-out limit, the entrainment and flooding limits are decreased. Therefore, a profound investigation of the operating limits of horizontal and slightly inclined two-phase thermosyphons is the first step in analyzing and developing flexible collector concepts for successful solar façade integration.

[1] As in solar industry the term "heat pipe" is also often used for two-phase thermosyphons, this paper refers to the term "heat pipe" as a hypernym for both heat transfer devices whenever no clear declaration is needed.