Wetting and film behavior of Propane inside geothermal heat pipes

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Increasing prizes for fossil fuels indicate the need for alternative and sustainable energy resources for cooling and heating of buildings. In Germany, e.g., 33% of the final energy consumption is used for room heating applications, Kaltschmitt et al. (2007), [1]. Shallow geothermal energy is obtained at depths of up to 400 meters, and it is usable as energy source for cooling and heating of buildings. There exist various closed systems of borehole heat exchangers, like geothermal u-tubes, coaxial tubes, heat pipes and energy piles. For heating applications ground heat pumps are necessary to increase the temperature level up to the required heating temperature, [2].

This paper deals with visualisation of falling film flow inside a gravitational driven heat pipe whereby heat pipes in general have been widely investigated in the past. The first applications for extracting heat from the ground by means of heat pipes were used to stabilize pipeline and railway fundaments, e.g. [3], or to heat highways and bridges, e.g. [4], [5]. Nowadays heat pipes are an alternative solution for geothermal energy use for heating applications. Thereby the heat pipe mechanism transfers heat very efficiently which can be a big motivation for users, e.g. house owners, see [6] and [7].

The efficiency of heat pipes depends, e.g., on the wetted inner tube surface due to the principle of falling film evaporation. To achieve a high evaporation rate a nearly closed liquid film down to the lower end of the pipe is required. The liquid film spreading depends on several properties of the heat pipe like pipe material, surface roughness, inclination angle, length as well as the operating regime [8]. The mechanism of geothermal heat pipes is strongly connected with falling film evaporation and condensation. An overview of the numerous publications which studied formation and structure of falling liquid films has been given by Philipp et al. (2006), [9] and various characteristic wave shapes have been presented by Gross et al. (2009), [10].

The research topic of the present contribution is focused on processes inside geothermal heat pipes operated with propane having dimensions of approximately 100 m in length and 53 mm inner diameter. Therefore no standard measurement technique is available to investigate especially the falling liquid film, so visual observations are necessary. A test setup with a special pressure lock system for the heat pipe’s head was developed, whereby a miniature camera can enter the heat pipe’s section, see also [11].

The first results of the investigations with focus on liquid pool during the starting process are shown in Fig. 1, whereby Fig. 1(1a) presents the situation before starting the heat pump...
operation. Approximately one sixth of the inner pipes surface is wetted. With the starting the heat pump system the wetted area decreases rapidly in few seconds, Fig. 1(1b – 2b), until a total dry surface is visible, Fig. 1(2c). So for the arriving liquid film it is always a first wetting, which is attended by a nebulous vapor which seems to flow downwards with the liquid film, see Fig. 2(1a – 1b). Temporally the liquid film becomes visible and the nebulous vapor gets more and more transparent until it’s only visible next to the liquid film surface and the rivulet edges, see Fig. 2(1c).

Figure 1: Heat pump off - wetted area with propane liquid pool - (1a); heat pump on – surface: dry out – pool: starts surface evaporation transition to pool boiling (1b) – (2c); 86.5 m depth

Figure 2: View in pipe with arriving liquid film with nebulous vapor (chronological order 1a – 1c)

Further investigations are concentrated on the time-dependent liquid distribution along the heat pipe, the liquid inlet and the liquid pool characteristics in comparison to heat output and temperature profile.

The final paper will contain measured temperature profiles along the heat pipes depending on the operating regime and first interesting results of the visual observations of the falling liquid film inside the geothermal heat pipe.

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