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# Comparative study of a novel liquid–vapour separator incorporated gravitational loop heat pipe against the conventional gravitational straight and loop heat pipes – Part II: Experimental testing and simulation model validation

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ABSTRACT

Aim of the paper is to report the experimental study of a novel liquid–vapour separator incorporated gravity-assisted loop heat pipe (GALHP) (T1), against the conventional GALHP (T2) and a gravitational straight heat pipe (T3). Based on the results derived from the theoretical analyses and computer modelling, three prototype heat pipes, one for each type, were designed, constructed and tested to characterise their thermal performance under a series of operational conditions. By using the experimental data, the computer simulation model reported in the authors' previous paper was examined and analysed, indicating that the model could achieve a reasonable accuracy in predicting the thermal performance of the three heat pipes. Under the specifically defined testing condition, T1 has more evenly distributed axial temperature profile than the other two heat pipes (T2 and T3). The start-up timings for T1, T2 and T3 were 410 s, 1400 s and 390 s respectively, indicating that the heat transfer within T2 was affected by the larger evaporator dry-out surface area and restricted evaporation area. The overall thermal resistance of T1 was 0.11 °C/W, which was around 20% and 50% that of T2 and T3. The tested effective thermal conductivity in T1 was 29,968 W/°C m, which was 296% and 648% that of T2 and T3, and 7492% that of a standard copper rod. It is therefore concluded that the novel heat pipe (T1) could achieve a significantly enhanced heat transport effect, relative to T2, T3 and standard cooper rod. The experimental results derived from this research enabled characterisation of the thermal performance of T1, relative to other heat pipes, and validation of the developed computer simulation model derived from the authors' previous research. These two parts researches in combination will enable design, optimisation and analyse of such a new GALHP, thus promoting its wide application and achieving efficient thermal management.


## 1. Introduction

Loop heat pipe (LHP) is a reliable thermal mechanism, which has been developed in different configurations and types for different applications, e.g., satellites/spacecrafts [1–3], electronics [4–6] and heat-recovery systems [7–9]. In recent years, application of the LHP in solar energy field has attracted the growing attention owing to the fast development of renewable energy technologies [10–16], of which the LHPs normally work under the gravity-assisted operational conditions. A novel gravity-assisted LHP (GALHP) with the top-positioned vapour–liquid separator has been proposed in the authors' previous research [17] that aimed to overcome the inherent problems exhibited in the conventional straight and loop heat pipes.

In authors' previous works [13–16], the new LHP has been applied to act as the thermal absorbers in solar photovoltaic/thermal and solar thermal facade systems. However, the fundamental mechanism of such a LHP and its actual capacity for enhancing the heat transfer relative to the conventional heat pipes have not yet been investigated. To fill up the shortfall, a comparative study of such a novel GALHP (T1), against conventional GALHP (T2) and

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**Nomenclature**

| | | | |
|---|---|---|---|
| $A_c$ | cross-sectional area, m$^2$ | $\overline{X}$ | average value |
| $CR$ | correlation coefficient | | |
| $E$ | error | *Subscripts* | |
| $k$ | thermal conductivity, W/°C m | $a$ | adiabatic section |
| $L$ | length, m | $cond$ | condenser |
| $n$ | number | $eff$ | effective |
| $\dot{Q}$ | applied heat load, W | $eva$ | evaporator |
| $R$ | thermal resistance, °C/W | $exp$ | experiment |
| $S$ | standard deviation | $ll$ | liquid line |
| $T$ | temperature, °C | $sim$ | simulation |
| $\bar{T}$ | average temperature, °C | $v$ | vapour |
| $U$ | uncertainty ratio | $vl$ | vapour line |
| $X$ | value | | |

gravitational straight heat pipe (T3), was conducted both theoretically and experimentally. The theoretical studies in relation to these heat pipes have been reported in the previous paper [17], whilest experiment related works will be reported in this paper.

## 2. Design and fabrication of the three heat pipes

### 2.1. Heat pipes design

Based on the results derived from the theoretical and computer simulation studies reported in the author's earlier paper [17], three heat pipes, configured as T1, T2 and T3, were designed and presented in Fig. 1 respectively. For convenience of comparison and analysis, the same dimensions and materials were applied in the design process. For the three evaporators, their lengths all remained 550 mm and diameters fixed to 22 mm. Within the inner surfaces of the evaporators, the compound screen mesh wick structure was applied to each of them, thus creating a uniform capillary inner surface that would break up the fluid surface tension and help distribute the fluid evenly across theses surfaces. For the three condensers, they were all fixed with the same sized steel cooling jackets, which were 150 mm in length and 105 mm in diameter. For the vapour and liquid transport lines, the three types of heat pipes were configured differently, as shown in Fig. 1.

### 2.2. Heat pipes construction

Construction of the heat pipes made use of a number of relevant mechanical processing skills including machining, welding, chemical cleaning and nondestructive testing [18,19]. Fig. 2(a) and (b) present the manufacturing procedures applied to the three heat pipes. Cooper, which is the most common heat conductive material, was selected to make the heat pipes' evaporators, condensers and other accessories, whilst the double screened copper meshes sized of 160 mm × 60 mm were used to act as the wicks of the heat pipes' evaporators. To ensure that the meshes can reach the tight attainment to the inner surface of the evaporators, the diffusion approach was applied when taking up the meshes assembly. In order to achieve a satisfactory wetting condition, the evaporators, condensers and the wicks were carefully cleaned by applying the demineralised water; this action was stopped until the water droplets immediately spreaded across the targeted surface.

For the T1 heat pipe, a smaller-sized copper pipe was flared into the '工'-type and then fitted into the top end of the evaporator using the welding treatment, thus forming up the unique vapour–liquid separator structure. The heat pipes' condensers were inserted into

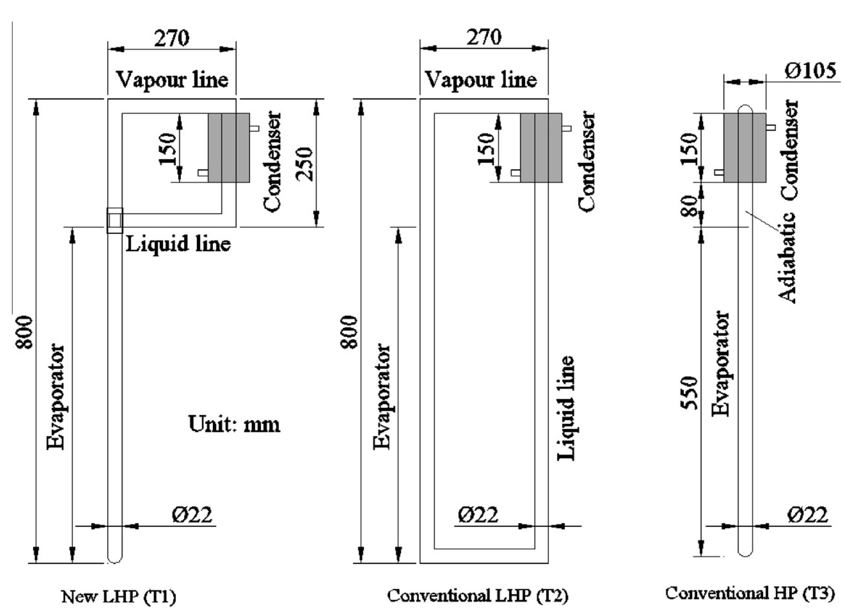


**Fig. 1.** Dimensional design of the three different heat pipes.