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A method of measuring capillary rise in a heat pipe

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INTRODUCTION

DETERMINATION of the maximum capillary rise in the wick structure of a heat pipe is of paramount importance for the prediction of its performance. In a formed heat pipe the capillary rise cannot be determined by any direct method, although some indirect methods [1–3] have been utilised. Nevertheless, the need for the measurement of capillary rise for finished heat pipes remain. Once the maximum lift height has been determined, the minimum effective radius of the capillary structure can be calculated and hence the capillary pumping pressure can also be obtained. In this paper we describe a method of measuring maximum capillary rise of a finished heat pipe by using a radioactive tracer technique.

DESCRIPTION OF THE EXPERIMENTAL APPARATUS

The heat pipe of length 40 cm was constructed from copper tube having inner and outer diameters of 5.7 mm and 10.5 mm, respectively. The sintered wick structure was formed inside the heat pipe from copper powder of mesh size 400 and left a vapour space of diameter 2.7 mm.

The measurement system (shown in Fig. 1) consisted of a 50 × 50 mm NaI (T) scintillation detector followed by preamplifier (PA), pulse amplifier (A), pulse height analyser (PH) and decade scaler (DS). Power supplied to the detector was from a stabilized high voltage power supply (HV). A lead collimator of slit diameter 5 mm was placed before the NAI (T) crystal for collimation of the beam incident on the detector.

EXPERIMENT AND RESULTS

The heat pipe was constructed with open ends. One end of the pipe was immersed in the radioactive solution and it was kept in the solution for approx. 24 h so as to allow the complete capillary rise of the liquid in the heat pipe wick structure. The pipe was then slowly lifted off from the liquid container and shifted to the radiation counting system. During shifting of the pipe adequate precautions were taken so that no radioactive liquid spilled and no contamination was made in the laboratory or the counting system. The heat pipe was mounted on a rack and pinion arrangement so that it can be moved

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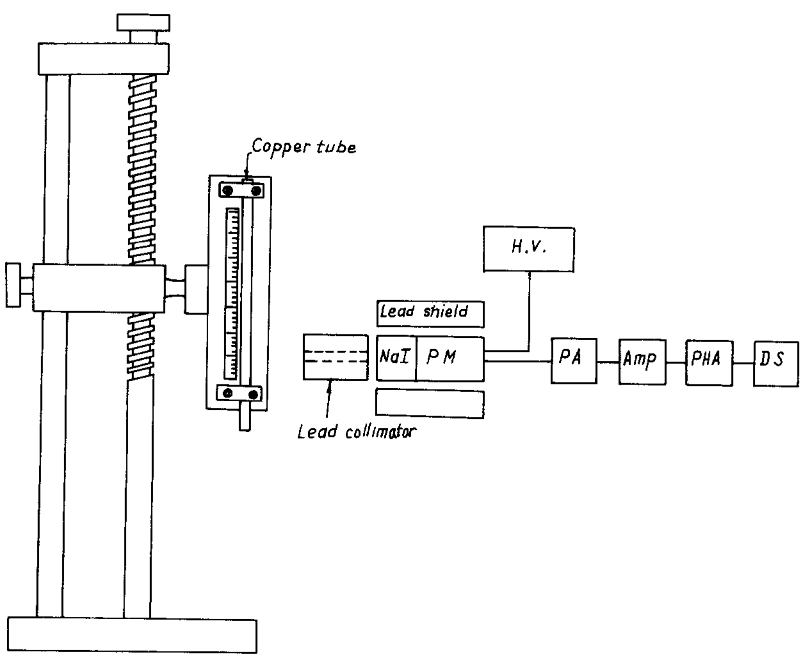

FIG. 1. Schematic diagram of experimental arrangement.

Table 1.

Height of liquid column (cm)	Surface tension of the liquid at 20°C (dyne cm^{-1})	Effective minimum pore diameter (cm)
16.5 ± 0.25	72.59	0.0166 ± 0.0002

vertically at a slow rate. The heat pipe containing a column of radioactive liquid, was then placed vertically in front of the horizontal detector system. The recorder system showed counts while the pipe moved vertically downward till a point is reached where the counts become equal to the background counts. The length of the pipe up to which the counts remained the same before falling off to the background level gave the height of the liquid column in the heat pipe raised by capillary action. Table 1 gives the experimental value of the maximum capillary rise and the minimum effective pore diameter of the capillary structure.

CONCLUSIONS

This method of measuring maximum capillary rise is very straightforward. The experimental accuracy is only limited by the diameter of the lead collimator of the radiation counting system. The main difficulty with this method is that of handling a radioactive solution and the precautions necessary for this, but hazards can be minimised by choosing a radioactive solution with a small half-life. Since most of the radioactive solutions are not normal heat pipe liquid, the data for maximum capillary rise cannot be directly used but values obtained for minimum pore diameter of the wick structure and the known values of the physical properties of normal heat pipe liquids enable one to obtain the maximum capillary rise or the capillary pumping pressure.

As the heat pipe was 40 cm in length and the liquid front in the wick was about 20 cm below the other open end, hence the possibility of any mass transfer and the consequent lowering of the actual value of the equilibrium height is negligible.

Even if there is any mass transfer for the long period the tube was kept in the liquid solution, the traces of radioactivity left at the maximum height attained by the capillary rise would be detected by the detection process employed in the present experiment.

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Unsteady free convection flow on a rotating flat plate under nonuniform gravity

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NOMENCLATURE

C_f	local skin friction coefficient
F	reduced stream function
F''_w, G'_w	surface skin friction and heat transfer parameters, respectively
$g(\xi), g_0$	nonuniform and uniform gravity fields, respectively
G	dimensionless temperature
Gr_x, k	local Grashof number and thermal conductivity, respectively
Nu, Pr	local Nusselt and Prandtl numbers, respectively
$P(\xi), S_w(\xi)$	dimensionless wall temperature function and wall temperature, respectively
q_w	local heat transfer rate at the surface per unit area
Re_x	local Reynolds number
t, t^*	dimensional and dimensionless times, respectively
T, T_w	temperature and wall temperature, respectively
u, v	velocity components in x and y directions, respectively
x, y	distances along and perpendicular to the surface
x_0	distance of leading edge of the plate from the centre of rotation.

Greek symbols

β	bulk coefficient of thermal expansion
ε	constant
η, ξ	transformed coordinates
μ, ν, ρ	dynamic viscosity, kinematic viscosity and density, respectively
φ, ψ	function of t^* and stream function, respectively
ω	angular velocity of rotating plate.

Superscript

$'$	prime denotes differentiation with respect to η.

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