Performance Simulation of a Heat Pipe Guarded Hot Plate Apparatus for Thermal Conductivity Measurement

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The ASTM C-177-10 standard establishes the criteria for the laboratory measurement of the steady state heat flux through flat homogeneous specimens when their surfaces are in contact with solid parallel boundaries held at constant temperatures using the guarded hot plate apparatus. In order to make easier the apparatus construction, to improve the accuracy of thermal conductivity measurement and to simplify the analyses for calculating the mean plate surface temperature, a circular line electric resistance has been used at precisely specified locations of the metered section and primary guard plates. The uncertainty of thermal conductivity measurement with a NIST apparatus at 300 K is claimed to be ± 1 %. This paper deals with the substitution of the electric resistances by heat pipes embedded in aluminum plates, for measuring the thermal conductivity of an insulating material, thus making the plate temperature much more uniform. The performance simulation was made with an apparatus that consists of cold, hot and guard plates, together with insulating material and specimen, both with a 0.05 W/m.K thermal conductivity value. Solving numerically the 2D energy equation for the whole system, it can be shown that the temperature uniformity in both hot (at 50 ºC) and cold (at 30 ºC) plates is better than 0.01 K in the metered section, with the ambient at 25 ºC and convection coefficient of 10 W/m².K. The maximum temperature difference along a plane parallel to the hot and cold plates in the metered section of the specimen is less than 0.17 K, less than 2 % of the imposed temperature difference (0.4 K), as required by the standard for lateral uniformity. The simulation also shows that because of lateral heat losses, heat supplied to the hot plate must be slightly more (2.5 %) than the ideal configuration (1 D flow), approximately independent of the imposed temperature difference between hot and cold plates, which makes the correction easier.