

Review Article

# A Review on the Utilization of Guarded Hot Plate Apparatus for Obtaining Thermal Conductivity

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## I N F O

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## A B S T R A C T

The current paper addresses a brief overview of various works carried out to obtain the thermal conductivity of engineering materials by using a guarded hot plate apparatus. There are various types of operators for measurement of thermal conductivities and are available in different designs and varied ranges of thermal conductivities and temperatures. Guarded hot plate apparatus is one of the apparatus which is successfully employed for measurement of thermal conductivity in which there is a heating plate sandwich in the middle of the material that is heating plate will remain in the middle of a material having same directions and the material is kept on its top and bottom side. The underlying principle of this apparatus is Fourier's Law of heat conduction. Overall it was observed and depicted that various researches have used this apparatus as it is capable of measuring the thermal conductivity of a wide range of materials like insulators having very low thermal conductivity and good conductors having very high thermal conductivity values.

**Keywords:** Thermal Conductivity, Temperature, Guarded Hot Plate Apparatus

## Introduction

A single material or combination of a variety of materials that are used to hold back heat flow is called insulation.<sup>1</sup> These materials can be of any size, color or texture. For protecting the insulation material from various mechanical as well as environmental damage various finishes are used.<sup>2</sup> If we talk about the use of thermal insulation material, it is used in a variety of buildings and refrigerators to block the heat flow.<sup>3</sup> Even in Air Conditioning systems insulation material plays a major role in energy efficiency.<sup>4,5</sup> Building dwellings are often insulated so that thermal comfort is economically achieved by an air conditioner.<sup>6</sup> If the wastage of energy resources has to be reduced/minimized, an insulation material is used which has high performance (low thermal

conductivity).<sup>7</sup> A lot of work is going on various materials in which considering the property of thermal conductivity of materials quite significant in the design process.<sup>8</sup>

In porous insulation material, the heat transfer mechanism consists of various heat transfer phenomenon such as:

- Heat conduction by solid material
- Radiative heat transfer
- Heat conduction and convection by inner gas

Thus, accordingly heat transfer, which originates from solid, radiation and inner gas, is shown as follows:

- Solid thermal conductivity  $k_{\text{solid}}$  [W/(m K)]
- Radiative thermal conductivity  $k_{\text{rad}}$  [W/(m K)]
- Gaseous thermal conductivity  $k_{\text{gas}}$  [W/(m K)]

Herein, it is visible that the thermal conductivity of solid is represented by  $k_{\text{solid}}$  [W/(m K)], thermal conductivity in case of radiative, it is  $k_{\text{rad}}$  [W/(m K)] and lastly in case of Gaseous state thermal conductivity depicted by  $k_{\text{gas}}$  [W/(m K)].<sup>9</sup> By adding the thermal conductivities of solid, gaseous and radiative or it can be represented as the sum ( $k_{\text{solid}} + k_{\text{rad}} + k_{\text{gas}}$ ) of all the thermal conductivities is known as the effective thermal conductivity ( $k_{\text{eff}}$  [W/(m K)]) of porous insulation material.<sup>10</sup> When it comes to measuring effective thermal conductivity ( $K_{\text{eff}}$ ) of any flat plate insulation material, only one operator's name comes to mind, which is a Guarded Hot Plate (GHP) apparatus.<sup>11</sup> The thermal conductivity of any material can be measured precisely by its thickness also. The thermal resistance of any specimen during steady flow has measured through Fourier's Law.<sup>12</sup> Guarded hot plate apparatus is developed by combining a variety of parts which are shown in Figure 1, but major are:

- Flat-plate specimen
- Cold surface assembly
- Hot surface assembly

The specimen is sandwiched between the cold plate as well as hot plate assemblies. The insulation material is used to prevent the thermal interaction of the apparatus with the atmosphere.<sup>11</sup>

Hot plate assembly is formed by a combination of flat plate and guarded plate.<sup>13</sup> The main plate is placed in the middle of the hot plate assembly, attached to the specimen.<sup>14</sup> The main plate and guarded plates are used to heat with the help of the main heater and guarded heater respectively.

For maintaining the arbitrary temperature of the main plate the guard heater is controlled.<sup>15</sup> The main heater is required for controlling the (0 K) temperature between the main plate and guarded plate only then can the heat loss, which is occurred in the main plate to the guarded plate, will be reduced. Ideally, heat input that arises in the main plate flows to the metered area of the specimen.<sup>16</sup> Then, under the steady-state conditions, the specimen is formed in the metered section and that too in a one-dimensional template.<sup>17</sup>

Author (s)	Year	Materials considered/ tested	Remarks / Comment	Ref.
Matthias Rottmann et al.	2020	Perlite powders	Guarded hot plate (GHP) and transient hot-wire (THW) technique for measuring the temperature between 295 K and 1073 K for the two evacuated expanded perlite powders.	[18]
Inseok Yang et al.	2018	Thermal insulation materials in square-shaped	The thermal conductivity test of two specimens was done and their results are 0.044W m <sup>-1</sup> K <sup>-1</sup> and 0.025Wm <sup>-1</sup> K <sup>-1</sup> (approx.) with unilateral heat flow at temperatures between 100°C and 800°C.	[7]
K.S. Reddy et al.	2017	Porous materials	Square Garden Hot Plate is a very reliable equipment. Through which thermal conductivity of porous materials has accurately measured up to 3 w/m k.	[19]
Tatsuya Kobari et al.	2015	Insulation panel	The guarded hot plate apparatus is found trustworthy in finding the thermal conductivity of conventional insulation materials and the Vacuum Insulation Panel (VIP).	[11]
Christian Suryono Sanjaya et al.	2011	Pores of porous materials	This method can be used to measure two specimens that have the same or different thermal conductivity.	[20]
William C. Thomas et al	2011	Insulation materials	The thermal performance of the guarded hot plate operator can probably be controlled by mathematical modeling.	[21]
J. Xamán et al	2009		3 % is the standard deviation occurring through this the average temperature in the plates is obtained.	[22]
J. Willix et .al	1998	Food items	Thermal conductivity of 27 food items such as meats, fats, fish, butter, cheeses, ice cream, apples has been identified from this guarded hot plate apparatus within the temperature range of -40 to +40 °C.	[23]

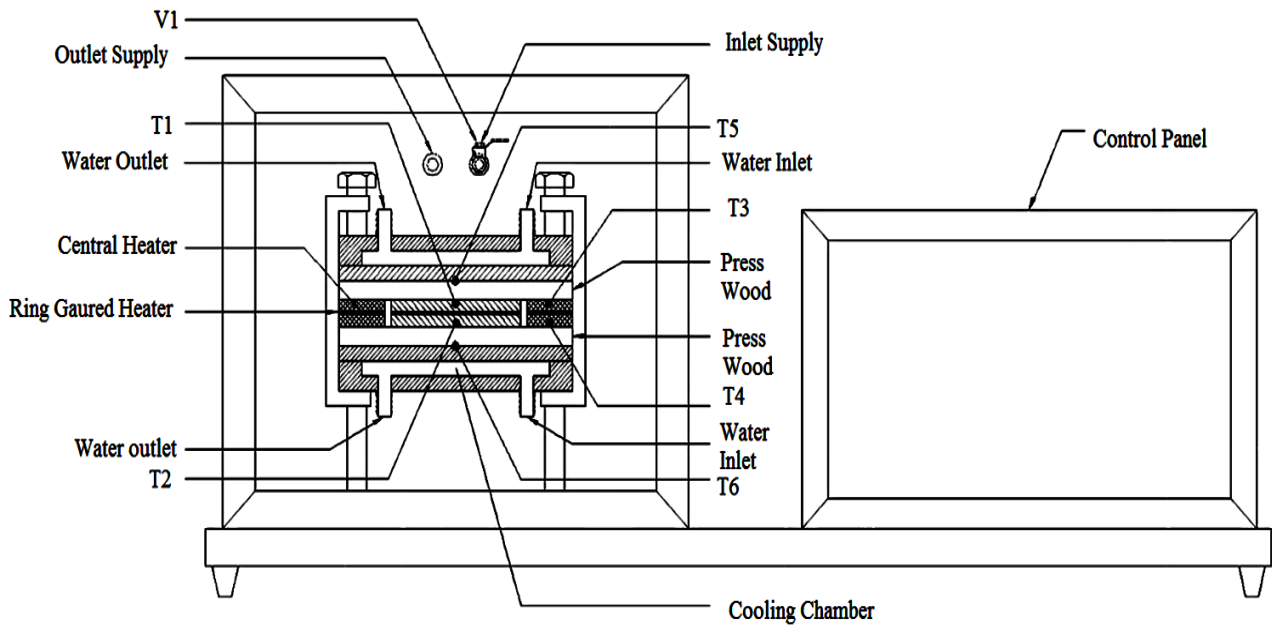


Figure 1. Guarded hot plate apparatus

## Literature Review

In this review table the data is entered by studying various research paper on the guarded hot plate apparatus:

Through this, it was clearly shown that the guarded hot plate apparatus has a variety of uses such as in August 1998 by J Willix et al. written in its paper that thermal conductivity of 27 food items such as (meats, fats, fish, butter, cheeses, ice cream, apples) has been identified from the guarded hot plate apparatus within the temperature range of  $-40$  to  $+40^{\circ}\text{C}$ . In June 2020 by Matthias Rottmann et al. Presented that the Guarded Hot Plate (GHP) and Transient Hot-Wire (THW) technique is used for measuring the temperature between 295 K and 1073 K for the two evacuated expanded perlite powders.

## Conclusion

This review paper clearly shows that the guarded hot plate apparatus has been used to observe thermal conductivity for many materials.<sup>24</sup> This apparatus plays a vital role in finding thermal conductivity of any insulation material before applying in any building or refrigerators etc. which holds back the heat flow.<sup>25</sup> The conclusion which can be made from the above literature with us is that there is a lot of developments which should be done for the measurement of thermal conductivity. As per international standards, it was seen that the variation of thermal conductivity values should be within plus-minus 10%. If this condition is achieved the apparatus meets the desired standards.<sup>26</sup> Thus, based on the techniques and methods carried out by various researchers for the development of search operators as shown in table one above, the people working in this direction make consider their works and guidelines to design

and develop similar apparatus meeting the international standards.<sup>27</sup>

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