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Thermal Conductivity Measurements of Kaolite

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Introduction

Testing was performed to determine the thermal conductivity of Kaolite 1600, which primarily consists of Portland cement and vermiculite. The material was made by Thermal Ceramics for refractory applications. Its combination of light weight, low density, low cost, and noncombustibility made it an attractive alternative to the materials currently used in ES-2 container for radioactive materials.

Mechanical properties and energy absorption tests of the Kaolite have been conducted at the Y-12 complex. Heat transfer is also an important factor for the application of the material. The Kaolite samples are porous and trap moisture after extended storage. Thermal conductivity changes as a function of moisture content below 100° C. Thermal conductivity of the Kaolite at high temperatures (up to 700° C) are not available in the literature. There are no standard thermal conductivity values for Kaolite because each sample is somewhat different. Therefore, it is necessary to measure thermal conductivity of each type of Kaolite. Thermal conductivity measurements will help the modeling and calculation of temperatures of the ES-2 containers. This report focuses on the thermal conductivity testing effort at ORNL.

Experimental

Thermal conductivity of the Kaolite was measured using a Hot Disk Thermal Constants Analyzer. A picture of the system is shown in Figure 1. A box furnace, with

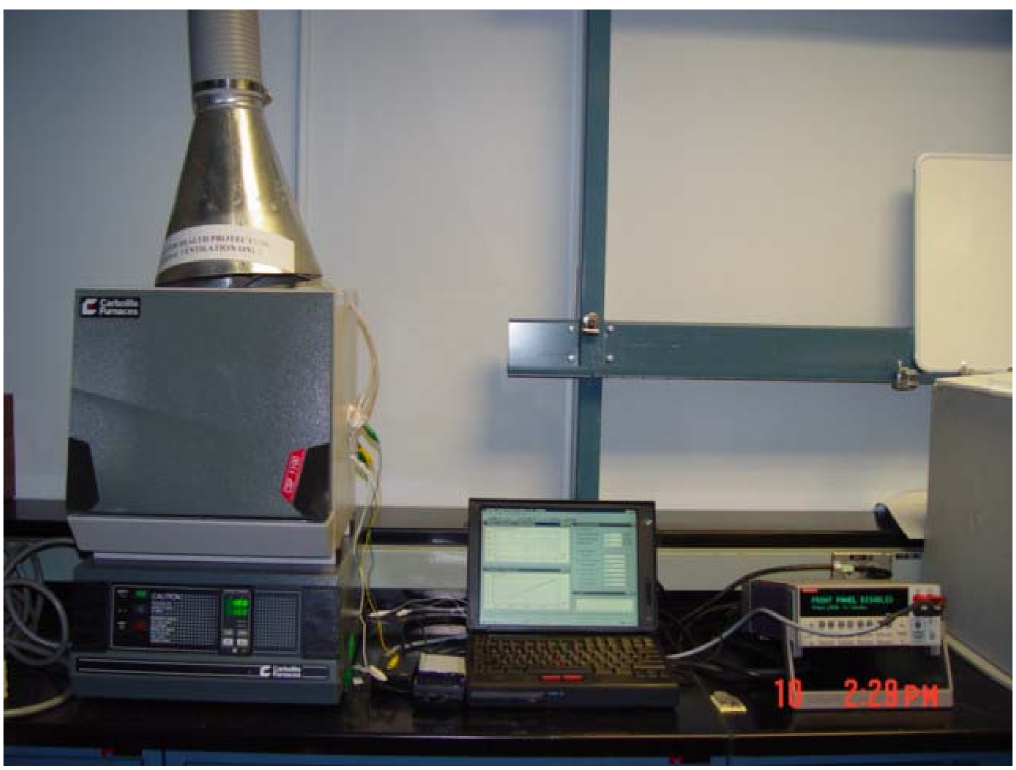

Figure 1. Experimental set up for thermal conductivity measurements.

maximum temperature of 1050° C, was used for high temperature tests. The Hot Disk sensor is a flat, thin, double-spiral nickel wire sandwiched between two mica sheets. The sensor is placed between two identical hockey-puck Kaolite samples (2” in diameter and 1” thick). During the measurement, the mica sensor acts as both a heater and a temperature sensor.

A typical test for Kaolite uses 0.05-watt constant-power heating for 80 seconds. The sensor temperature is recorded as a function of time. Thermal conductivity is then calculated directly from the experimental data. Detailed theory and experimental descriptions of the Hot Disk technique can be found in the references [1-3].

In order to perform high temperature measurements, special contacts were made from stainless steel. Four high temperature wires with insulation were connected to the mica sensor with the wires being fed through an opening on top of the furnace. A rectangular mica sheet with four screw holes was used as the support for the sensors. The four wires were connected to the contacts as shown in Figure 2. The mica sensor can be delaminated due to high temperature exposure, therefore, the sensor has to be replaced after a 600° C measurement. A heavy alloy block was placed on top of the sample to ensure good contact at the interface.

Figure 2. Kaolite samples and mica sensor used for high temperature testing.

Results and Discussion:

Thermal conductivities of six Kaolite samples were tested using the mica sensor. Since high temperature tests can destroy the sensor and only one set of samples was tested in the furnace, all the samples were tested at room temperature and then at 100° C. but only one sample was tested up to 600° C.

At room temperature and 100° C, the thermal conductivity values of the 6 Kaolite samples are similar, although the densities of the samples are grouped in 3 pairs at high, medium and low. The test results are shown in Table 1 for room temperature and Table 2 for 100° C. During the tests the humidity was not controlled in the laboratory or in the furnace. The samples did not have the same thermal history. For example, one set of sample was heated up from room temperature to 100° C, but the other 5 sets of samples had to wait outside the furnace. In addition, the local density of the sampling volume, i.e. ¾" diameter semi sphere, can also vary due the existence of large pores and

Table 1. Thermal conductivity of six Kaolite at 20° C (unit: W/mK)

Density (lb/ft3)	H 23.690	H 23.541	M 22.055	M 22.011	L 20.407	L 20.281
Test 1	0.188	0.183	0.152	0.198	0.165	0.172
Test 2	0.188	0.185	0.157	0.182	0.168	0.192
Test 3	0.191	0.181	0.167	0.198	0.169	0.181
Average	**0.189**	**0.183**	**0.158**	**0.192**	**0.167**	**0.181**
	High Density	**0.186**	**Medium Density**	**0.176**	**Low Density**	**0.175**

Table 2. Thermal conductivity of six Kaolite at 100° C (unit: W/mK)

Density ρ (lb/ft3)	H 23.690	H 23.541	M 22.055	M 22.011	L 20.407	L 20.281
Test 1	0.165	0.172	0.157	0.179	0.163	0.177
Test 2	0.152	0.172	0.157	0.191	0.163	0.179
Test 3	0.161	0.179	0.156	0.194	0.152	0.178
Average	**0.159**	**0.174**	**0.156**	**0.188**	**0.159**	**0.178**
	High Density	**0.166**	**Medium Density**	**0.172**	**Low Density**	**0.168**

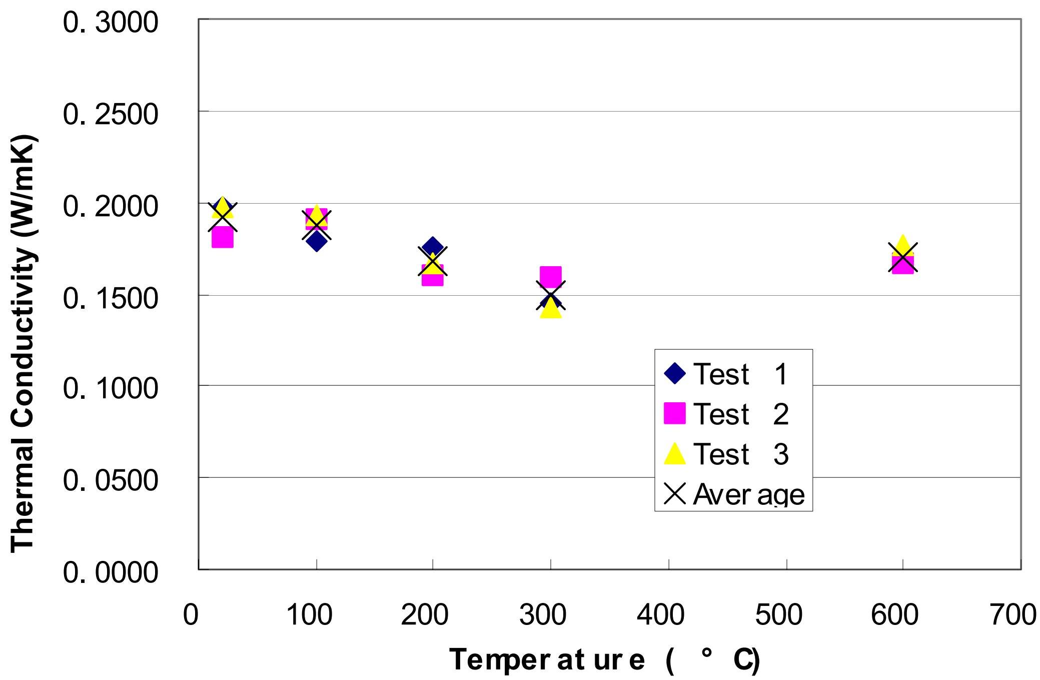

Figure 3. Thermal conductivity of Kaolite from room temperature to 600° C

Table 3. High Temperature Thermal Conductivity of Kaolite (unit: W/mK)

No. 323011258	Test 1	Test 2	Test 3	Average
20	0.1978	0.1815	0.1976	0.1923
100	0.1792	0.1913	0.1936	0.1880
200	0.1758	0.1601	0.1673	0.1677
300	0.1452	0.1592	0.1427	0.1490
600	0.1676	0.1665	0.1771	0.1704

density variation. Thermal conductivity results showed some scatter at these two temperatures.

The high temperature tests were performed on one medium density Kaolite sample. The thermal conductivity data are shown in Table 3. As shown in Figure 3, thermal conductivity values decreased as a function of temperature up to 300° C. This trend is consistent with ceramics and other insulating materials. At 600° C, thermal conductivity started to increase. This is also consistent with the fact that thermal radiation effect takes place in this temperature range. As temperature goes up, thermal conductivity of most insulating materials also goes up.

References:

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[3] V. Bohac, M.K. Gustavsson, L. Kubicar and S.E. Gustafsson, *Rev. Sci. Instrum.*, **2000**, 71, 2452

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