Mrs Kane

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THERMAL CONDUCTIVITY TESTS ON AN INSULATING CASTABLE MANUFACTURED BY CANADIAN REFRACTORIES LIMITED MONTREAL, QUE.

by

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INTRODUCTION

Canadian Refractories Limited requested that a series of thermal conductivity tests be carried out on their Micacrete-7 which is an insulating castable. There is no standard procedure for the preparation of test specimens for the determination of thermal conductivity of this type of insulation. It was decided to investigate several methods of test and tentatively establish a suitable means of arriving at thermal conductivities of insulating castables using CRL Micacrete-7 as the test specimens. Three procedures were selected for obtaining results after consultations were held with Canadian Refractories Limited. The company supplied 20 test samples, 9 in. x 4½" x 2½". The samples were cast in their laboratories and shipped to the Mines Branch. It was stated by the company that Micacrete-7 was recommended for use up to a maximum temperature of 2000°F.

PROCEDURE

The apparatus used meets the requirements of A.S.T.M. Designation C201-47 - Standard Method of Test for Thermal Conductivity of Refractories. In general the Standard Method of test for Thermal Conductivity of Insulating Fire Brick, A.S.T.M. Designation C182-47, was followed. Three specimen thermocouples were used giving three mean temperatures per control temperature.

Three separate thermal conductivity tests, A, B and C, were carried out. The procedure for them was as follows:

Test A (Lab 110) The bulk density of the specimens as received was determined initially. One set of specimens was then prepared and placed in the apparatus. The thermal conductivities were determined at three control temperatures, the maximum being 2000°F. The furnace was then cooled and the test material was examined.

Test B (Lab 110A) The Micacrete-7 was very soft and it had warped and shrunk considerably from test A. Consequently the test pieces were carefully removed, the pieces were fitted according to specifications and then reset in the tester in exactly the same positions as in Test A. The bulk density was not determined on this series because of the danger of the specimens flaking off during the measurement of dimensions. The thermocouples positions were the same as in Test A. The thermal conductivities were then determined for three control temperatures, the maximum being 1950°F.

Test C (Lab 110B) A separate set of specimens were fired at 2000°F for 4 hours in an electric laboratory kiln. The bulk density of four spare samples was determined. The bulk density of the samples used directly in the thermal conductivity test was not obtained because of the danger of damaging the soft friable material with the extra handling involved. The fired specimens were then set in the tester and the thermal conductivities were determined at three control temperatures, the maximum being 1995°F.

The procedure followed in determining bulk density was similar to that in ASTM Designation C134-41, Standard Methods of Test for Size and Bulk Density of Refractories. The main exception was that the thickness of each brick was measured by special calipers and not by the stack method.

A reheat test at various temperatures was also carried out to obtain a guide as to the amount of shrinkage which would take place. One specimen was heated at each temperature. The specimen was placed in an electric laboratory kiln and soaked at the required temperature for four hours. The shrinkage was then measured after cooling. The shrinkage at 1000, 1800, 1900, and 2000°F was obtained based on the original length.

RESULTS

The results of the reheat tests are as follows:

1000°F .... 1.13% shrinkage

1800°F .... 3.34% shrinkage

1900°F .... 3.35% shrinkage

2000°F .... 3.46% shrinkage

The results of the thermal conductivity tests are shown in Table 1.

Table 1 - Thermal Conductivity Values

Sample	Control Temp. °F	Mean Temp °F	Thermal Conductivity $\frac{Btu \times in}{sq\ ft \times hr \times °F}$
A - Unfired Micacrete-7 Laboratory Number 110	905	600	1.41
		426	1.32
		284	1.25
	1400	969	1.58
		663	1.36
		453	1.21
	2000	1473	1.90
		1014	1.55
		724	1.33

Table 1 - Continued

Sample	Control Temp. °F	Mean Temp °F	Thermal Conductivity Btu x in / sq ft x hr x °F
	900	619 456 318	1.15 1.11 1.07
B - Sample A fired in tester to 2000°F, cooled and reset. Laboratory Number 110A	1410	1013 734 518	1.33 1.22 1.13
	1950	1481 1061 769	1.58 1.36 1.22
C - Micacrete-7 fired in a laboratory kiln to 2000°F and then set in tester. Laboratory number 110B	900	640 502 ? 387 ?	1.17 1.06 ? 0.96 ?
	1400	1022 811 ? 629 ?	1.33 1.22 ? 1.13 ?
	1995	1487 1150 898	1.56 1.33 1.16

Note The mean temperatures and thermal conductivities in test C followed by a question mark were not obtained according to exact specifications. During the course of the 900 and 1400°F control temperature tests, it was discovered that the lower thermocouple did not have a suitable junction in the ice bath. Thus a constant error in the mean temperature and temperature difference from the top to bottom thermocouples and from the centre to bottom thermocouples was introduced during the course of the test. However, by inspection of the chart it was found that the correct lower thermocouple temperature was printed temporarily when ice was added to the ice bath. Thus it was possible to arrive at a close estimate of the proper value. The estimated value of the lower temperatures was used in obtaining the values followed by a question mark. All other values were obtained from a sensitive potentiometer as laid down by the A.S.T.M.

The bulk densities of samples A and C are shown in Table 2.

Table 2 - Bulk Density Values

Sample	Weight lbs	Length in.	Width in.	Thickness in.	Bulk Density lbs/cu ft
A (Lab 110) average of 10	2.16	8.97	4.48	2.50	37.2
C (Lab 110B) average of 4	1.82	8.65	4.33	2.41	34.8

DISCUSSION OF RESULTS

The results of the thermal conductivity tests on the previously unfired Micacrete-7 (A Lab 110) probably do not indicate the true thermal conductivity values of the material. Up to 900°F the shrinkage is relatively small. However, as the temperature gets higher the shrinkage becomes greater and cracks at the joints open up allowing the passage of a greater amount of heat than would go through a tightly packed insulation. At the same time the temperature gradient produces differential shrinkage between the top and bottom which in turn produces warping. The upper surface of the test specimens is at the furnace control temperature and the lower face of the test specimens is approximately at the calorimeter temperature which is usually approximately 85°F. Because of the temperature gradient, the density and texture of the specimen varies from top to bottom. As the temperature increases the Micacrete-7 gradually becomes softer and more friable. Some of the micaceous material tends to expand. However, the overall effect of increasing temperature is to produce increasing shrinkage. As shown from the reheat tests there is little difference in the total shrinkage between 1800 and 2000°F.

The thermal conductivity values of the previously unfired specimens were the highest of the three tests. This is due to the initial effect of firing on the specimen ingredients and to shrinkage and warpage. The results, especially those at the 2000°F control temperature are similar to very severe service conditions.

The results of the thermal conductivity tests on the Micacrete-7 which had been previously fired in the thermal conductivity apparatus (B Lab 110A) probably represent a true indication of the conductivity values of the insulation in this condition. The refitted pieces were laid in the tester with tight joints and since the shrinkage had been previously eliminated there was little danger of getting much more shrinkage or warpage. The test specimens represented an initial condition in which the material had been subjected to a temperature gradient similar to that in service. The main difference is that in service this castable is applied unfired and some shrinkage can be expected, mainly during the first firing. This is particularilly true if the hot face temperature approaches the maximum allowable of 1800 to 2000°F.

The thermal conductivity values of test B (Lab 110A) are consistently lower than those of test A (Lab 110). The results obtained in test B might be somewhat similar to mild service conditions where there is a small amount of shrinkage and warpage.

The thermal conductivity values obtained from test C (Lab 110B) represent thermal conductivities of the Micacrete-7 previously fired to 2000°F throughout the entire specimen. This situation would not likely be encountered in service conditions. There was no appreciable shrinkage of this sample during the test since it had mainly been eliminated during the initial firing. The thermal conductivity values were in the same range as those of test B for all mean temperatures.

From examination of Table 2 it is shown that the bulk density of Micacrete-7 is less when it is fired to 2000°F than when it is in the unfired condition.

CONCLUSIONS

Micacrete-7 has approximately 3.5% shrinkage from 1800 to 2000°F. This factor affects the thermal conductivity values of the previously unfired material if the final control temperature of the test apparatus is raised to 2000°F. It was found under these conditions that the thermal conductivity values were higher than those from the other tests. The results would likely be similar to conditions encountered in very severe service. This type of test does not give a true indication of the thermal conductivity of the insulation.

The thermal conductivity results of the material fired in the test apparatus and then refitted give a good indication of the thermal conductivity of the insulation in service where shrinkage is negligible. The heat flow path is through the insulation only and not through insulation and shrinkage cracks. This method of test probably gives a better indication of the thermal conductivity than the method of obtaining results without previous heat treatment.

Firing the Micacrete-7 in a laboratory kiln at 2000°F and then obtaining the thermal conductivity produced results which were similar to those obtained by initially firing the test specimens in the thermal conductivity apparatus. The method of firing appeared to have very little affect on the thermal conductivity of Micacrete-7 provided the shrinkage and warpage was first eliminated.

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