Testing of the Thermal Resistance of DefendPak vs Vermiculite

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Background/Scope

DefendPak is an expanded post-consumer recycled glass material being marketed as “fire protection granules” for a wide range of fire classes including combustible metal and lithium-ion battery fires. Vermiculite is an expanded mica-like mineral common in insulation materials and lawn care products, as well as in some fire protection applications.

In an effort to compare DefendPak and Vermiculite as potential packing materials for the shipment of end-of-life or damaged lithium-ion batteries, the thermal resistance (e.g., insulative property) of both products was tested. To compare the thermal resistance of these two products, Chippewa Valley Technical College’s (CVTC) Fire Safety Center (FSC) developed a standardized test with which to compare the two products.

Methods

The goal of the thermal resistance test was to determine how quickly heat would transfer through 1.5 inches of each of the two test materials. The heat transfer rate was also compared to an air gap of 1.5 inches.

The test apparatus consisted of two ¼-inch think steel plates separated by a gap of 1.5 inches which could be filled with the test material of choice. On the outside of steel plate number 1, a 50,000 BTU torch was positioned horizontally at a distance of 6 inches and aimed at the center of the plate. On the outside of steel plate number 2, an array of five thermocouples was affixed to the plate to monitor the transfer of the torch’s heat through the plates and test material or air gap. Figure 1 provides an overview of the thermal resistance test setup.

As the heat of the torch transferred through the test material, the temperature at each thermocouple was recorded at a rate of one reading per second with a digital thermocouple recorder. A total of four tests were performed:

1. Air gap #1
2. Vermiculite
3. DefendPak
4. Air gap #2

The second air gap test was performed to verify that all test conditions (torch output, test chamber conditions, etc.) remained consistent for the entire duration of the test day.

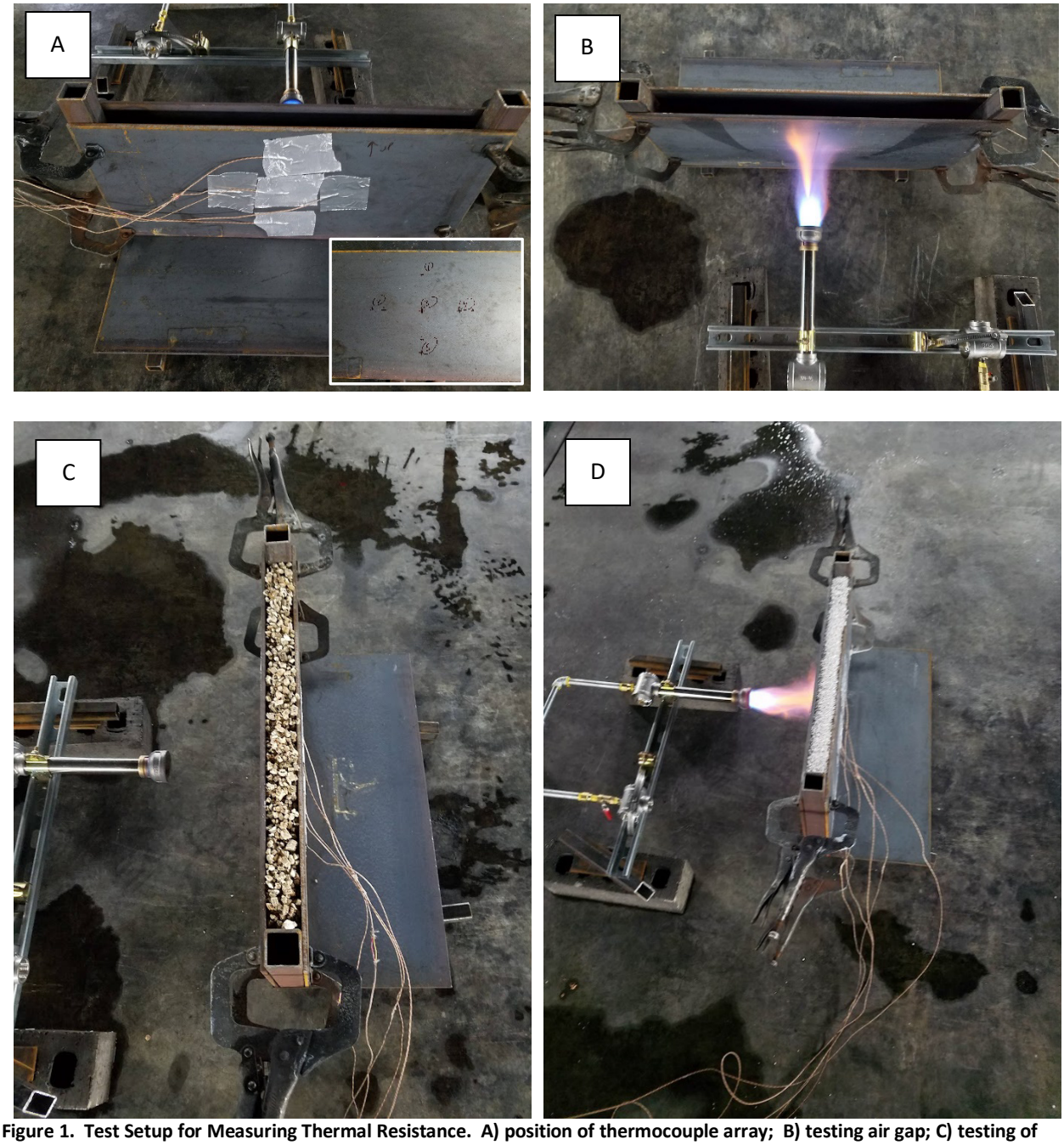

Figure 1. Test Setup for Measuring Thermal Resistance. A) position of thermocouple array; B) testing air gap; C) testing of Vermiculite; D) testing of DefendPak.

Results/Discussion

After all tests were completed and the data reviewed, thermocouple number 1 (positioned in the top-center of the plate) consistently displayed the highest temperature (e.g., the area of highest heat transfer) of all five thermocouples. Therefore thermocouple 1 was used exclusively to compare the thermal data from each of the tests.

To allow for a direct comparison of the heat transfer rate in each test, the point at which thermocouple number 1 reached 30 degrees C was assigned time zero (0:00) and the thermocouple temperatures were plotted against time (Figure 2). A high temperature threshold for the tests was set at 90 degrees C which was the point where the DefendPak-filled gap had reached near thermal balance with the torch's output.

A comparison of the time it took for thermocouple 1 to reach each 10 degree increment is displayed in Table 1, and a comparison of the temperatures at each five minute test interval are displayed in Table 2.

The air gap tests revealed a relatively high rate of heat transfer with a time to 90 C of 6 minutes 28 seconds (6:28) for the first air gap test and 6 minutes 51 seconds (6:51) for the second. The layer of Vermiculite in the test space increased the time to 90 C to 34 minutes 34 seconds (34:34), while an identically sized layer of DefendPak increased the time to 90 C to 2 hours 29 minutes 29 seconds (2:29:29).

A comparison of the heat transfer at specific time intervals also demonstrates a large difference in the insulative value of the tested products. After 10 minutes of testing, the two air gaps had risen to 121.7 and 116.6 degrees C, respectively; while Vermiculite kept the temperature to 52.0 degrees and DefendPak kept it to 44.1. At the 20 minute mark, the temperature had risen to 70.8 degrees with the Vermiculite-filled gap, but only 62.1 degrees with the DefendPak-filled gap. At 45 minutes, the temperature of thermocouple 1 was 99.3 degrees with the Vermiculite-filled gap and 76.5 degrees with the DefendPak-filled gap.

As can be seen in the temperature plot (Figure 2), the 1.5 inch layer of DefendPak was able to hold back the heat of the torch much more effectively than either a 1.5 inch air gap or a 1.5 inch layer of Vermiculite. The rate of temperature rise through the DefendPak layer had slowed to the point where a thermal balance was being reached; while within the same time period, the layer of Vermiculite was still transferring additional heat and the rate of rise had not slowed significantly before reaching the test cutoff of 90 degrees C. This demonstrates that DefendPak is not only a better insulator of heat, but that it is able to maintain its insulative properties over long time periods.

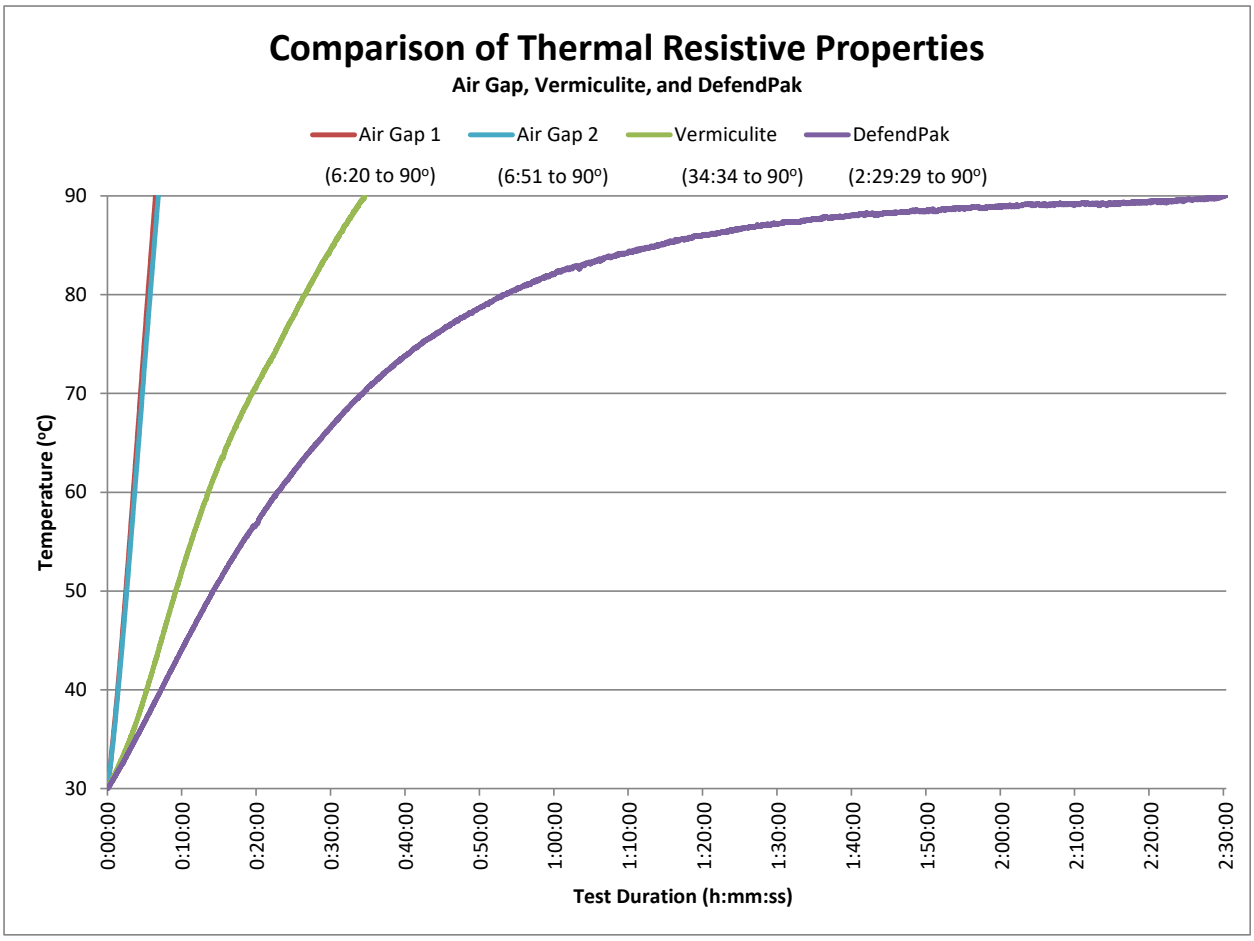

Figure 2. Thermal Resistance Test Results (Test Duration vs Temperature)

Table 1. Comparison of Thermocouple #1 Temperatures at 10 Degree Intervals

	Air Gap 1	Air Gap 2	Vermiculite	DefendPak
Time to reach 40°	0:01:23	0:01:27	0:05:16	0:07:11
Time to reach 50°	0:02:29	0:02:36	0:09:10	0:14:09
Time to reach 60°	0:03:29	0:03:40	0:13:31	0:22:45
Time to reach 70°	0:04:27	0:04:42	0:19:24	0:34:11
Time to reach 80°	0:05:26	0:05:45	0:26:27	0:53:09
Time to reach 90°	0:06:28	0:06:51	0:34:34	2:29:29

Table 2. Comparison of Thermocouple #1 Temperatures at 5 Minute Intervals

	Air Gap 1	Air Gap 2	Vermiculite	DefendPak
0:05:00	75.6	72.9	39.3	36.7
0:10:00	121.7	116.6	52.0	44.1
0:15:00			62.8	51.0
0:20:00			70.8	56.8
0:25:00			77.9	62.1
0:30:00			84.6	66.6
0:35:00			90.4	70.6
0:40:00			95.1	73.8
0:45:00			99.3	76.5
0:50:00				78.7
0:55:00				80.5

Conclusion

Test results show that DefendPak is a much more thermally resistant material than Vermiculite. A 1.5 inch gap of DefendPak resisted the heating of the test apparatus thermocouple to 90 degrees C for over 4.3 times as long as a 1.5 inch gap of Vermiculite did. While the choice of packing materials for lithium-ion batteries should likely include a consideration of multiple properties, the high degree of thermal resistance of DefendPak makes it a very good candidate when considering any packaged product that may spontaneously heat and/or combust.