Determining the Specific Heat Capacity of a Battery Pack

Illustrative Example and Description of Method

SPECIFIC HEAT CAPACITY OF A BATTERY PACK

Test aim

Determination of the specific heat and heat capacity of an example battery pack, consisting of 12 '18650' size rechargeable lithium-ion batteries (18 mm in diameter, 65mm in height) over a temperature range in one rapid test. The test was carried out over the temperature range of interest; 25°C to 55°C. Calorimeter calibration had been performed prior to testing using aluminium standard; block of approximately equal mass and size to the battery pack. This is discussed in the appendix section.

The aim is to obtain the heat capacity of the battery pack (Joules per Degree) and the 'specific heat' (Joules per Gram Degree). It should be noted that since the battery/module/pack is built from a variety of materials the 'specific heat' is an 'average or composite specific heat' . With this data any further tests on batteries will yield results where temperature rise data will be converted (automatically by ARCCal+ software) to Enthalpy (joules) and rate of temperature rise data will be converted to Power (Watts)

Test Procedure

The battery pack to be tested consists of 12 cylindrical lithium-ion cells arranged in 2 rows of 6. In this example, the cp-heater mat is sandwiched between these two rows in a central position in order to ensure all the heat emitted is transferred into the batteries. The heater is connected to a variable voltage power supply.

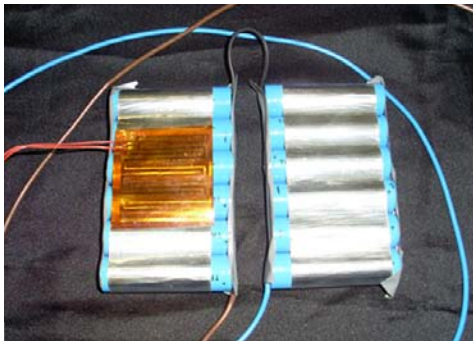

Fig. 1 – Battery pack in preparation

To seal the heater and batteries firmly together, they are wrapped in aluminium tape. The battery terminals are insulated with glass tape to prevent a short circuit in the battery pack.

Prior testing had determined that the mass of the heater and tape was insignificant relative to the mass of the battery. (If the battery is of low mass then a simple correction is applied). The control thermocouple is taped to the outside of the battery pack, again using glass tape.

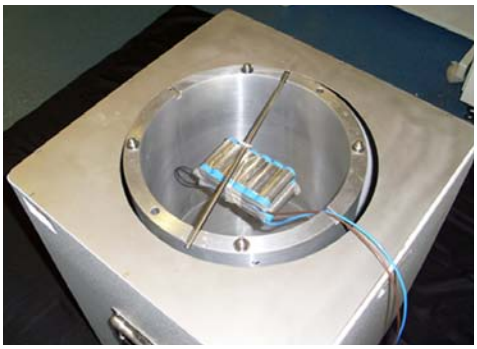

Fig. 2 – Battery pack wrapped in aluminium tape suspended within the calorimeter

The battery pack is suspended within the calorimeter using woven glass sleeving ensuring it is not in contact with the sides of floor of the chamber. Figure 2 shows the battery suspended from the lid.

The lid is then secured. The wires from the heat and the thermocouple cable exit the calorimeter and are connected to the power supply, the thermocouple is connected.

The Accelerating Rate Calorimeter Cp test is initiated. Once the test begins, the power supply is activated, in this test to 8.5 volts at a current of 0.23 amps. The test takes 2 hours, in which time the sample will reach of a temperature of around 60°C from its starting temperature of 25°C.

Data from the test can then be analysed in the ARCCAL+ software. This gives individual values for time, temperature and temperature rate (in units of degrees centigrade per minute). The data can be exported to a numerical software package such as Microsoft Excel if required.

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Results

In this dynamic test the heat capacity/average specific heat can be determined at all temperatures – this is much more advantageous than any semi-isothermal or heat step test as there is more data available and the data is obtained in a short time

The raw data is shown in Figure 3. THT has a Wizard to calculate the specific heat and heat capacity at any temperature (or over any temperature range). This is shown in Figure 4.

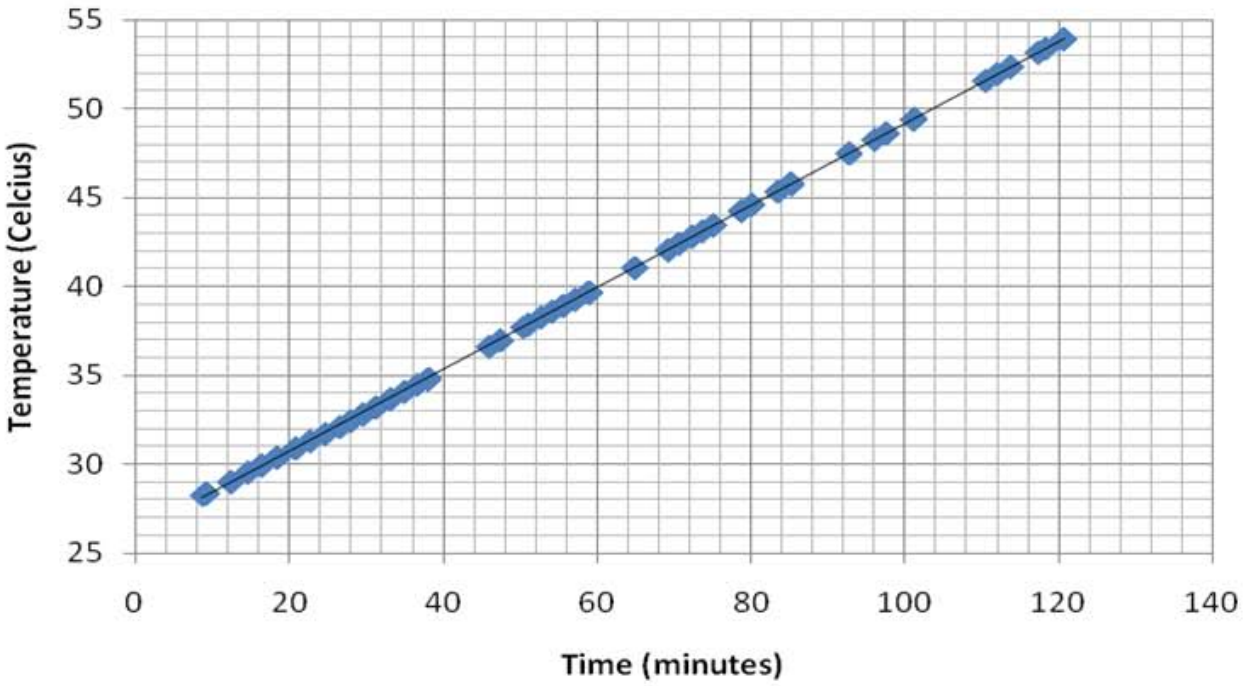

Fig. 3 – Temperature versus time plot taken from Microsoft Excel

Taking this value for the temperature rate (at or averaged over a temperate range), and with knowledge the mass of the battery pack and the voltage and current supplied to the heater, we can then calculate the Cp value and heat capacity using the heat capacity wizard software

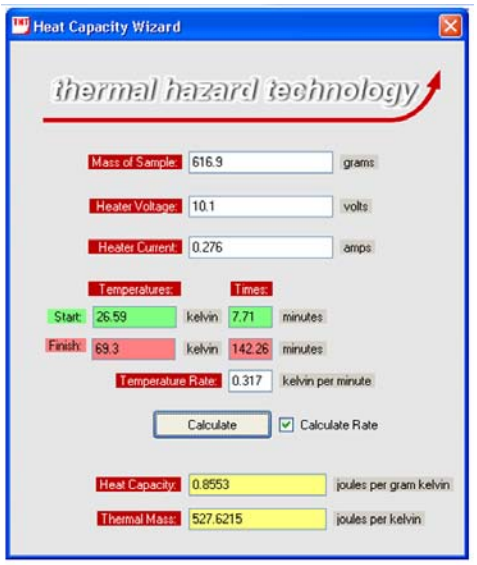

Fig. 4 – Heat capacity wizard interface

From this test an average (mean) Cp value over the entire temperature range of the experiment of 0.83 J/gK is obtained.

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This test was carried out over the temperature range 25°C to 55°C. The table (Table 1) provides values for the specific heat capacity at differing temperatures. It can be seen that the value does not change over the temperature range. This also shows that the THT specification of values to a repeatability of better than 5% and THT would suggest that the reproducibility is also better than 5%. Appropriately, the results are quoted to a precision of 2 decimal places. With standard materials giving repeatable values to within 5%, THT would suggest that the accuracy of this and other data obtained by the instrument is within 5%.

Temperature, T (°C)	Specific Heat Capacity, Cp (J/gK)
30	0.85
35	0.82
40	0.84
45	0.81
50	0.84

Table 1. – Heat capacity values obtained at various temperatures

In other tests performed on the same battery pack and on a variety of batteries/packs, heat capacity values reproducible to within 5% were obtained.

This test is a short test and has been shown to give reliable and accurate values of specific heat and heat capacity over a range of temperatures. The value obtained is then simply put in to the battery test set up software when (for example) carrying out a fast discharge battery test – the data then will be graphically presented in units of heat (enthalpy ie joules) and power (watts).

To show that the method is reliable and produces accurate results tests have been carried out with ‘standard materials’ of known specific heat. Within the THT specific heat option standard materials are provided. The appendix below gives information on ‘calibration’.

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Appendix

APPENDIX

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Prior to battery heat capacity testing in the Accelerating Rate Calorimeter, the test procedure was evaluated, and the device was proven. And prior to testing generally tests with standard samples should be run. This is illustrated here using aluminium blocks in place of the batteries. The method of the test is the same as that described in the battery test. The sample was tested three times. With the heater set to 100%, 50% and 25% power in each case.

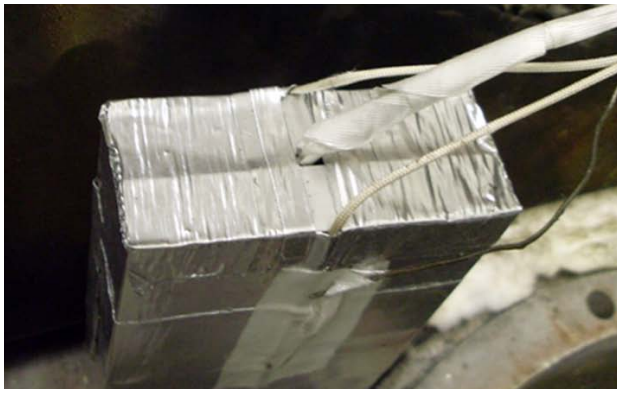

Fig 5 – The aluminium block setup prior to placement in the calorimeter

Values obtained for aluminium Cp:
At 100% heater power: 0.91 J/gK, At 50% heater power: 0.92 J/gK, At 25% heater power: 0.90 J/gK.
Literature value for Cp of aluminium in standard conditions: 0.90 J/gK

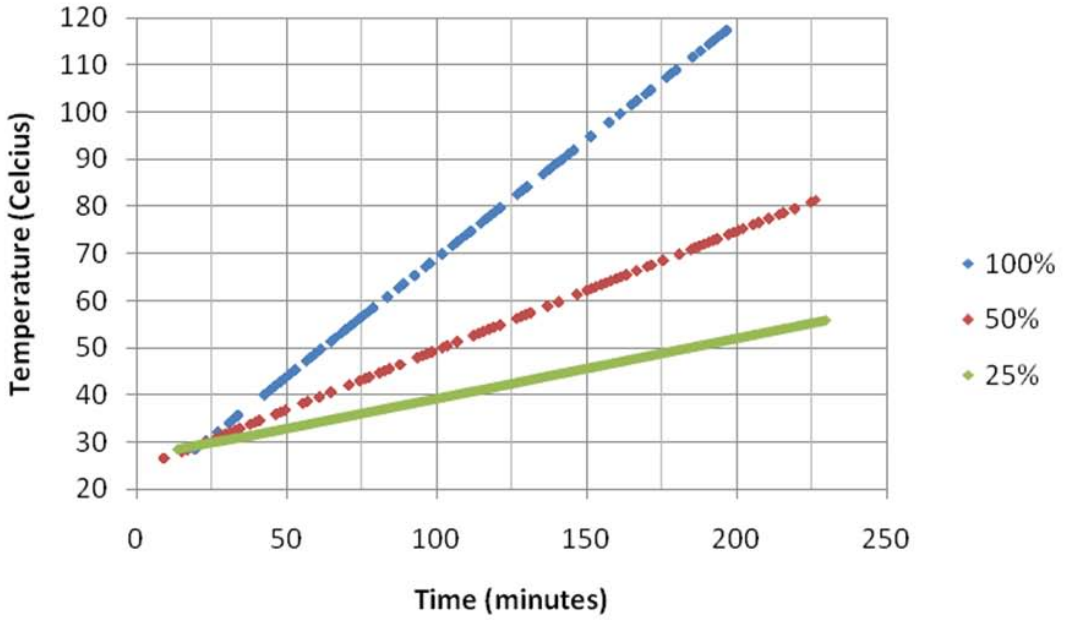

Fig. 6 – Aluminium blocks temperature versus time graph for three heater power settings

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