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Representative Test Procedure for Customer Evaluations

A constant current discharge test may be useful for customer evaluation of the product prior to application testing. All ultracapacitors are stored discharged for safety. We recommend completely discharging any capacitors that will not be installed into equipment.

Below is a list of equipment required to perform a typical constant current discharge test:

- bi-directional power supply (supply/load) OR
- separate power supply and programmable load (constant current capable)
- voltage vs. time measurement and recording device (digital scope, or other data acquisition)
- current vs. time measurement and recording device (optional if you can trust the power supply and load settings)

Before testing, connect data acquisition equipment to the device terminals, and set recording speeds as fast as reasonably possible (<<100msec preferred, the faster, the more accurate the calculations).

Setup

Set the power supply to the appropriate voltage and current limits, and turn the supply output OFF.

The current limit can be anything at or less than the maximum rated current for the cell. When performing repetitive high current testing, cooling air should be provided.

The voltage limit is the maximum cell voltage, times the number of cells in series. A single cell should be limited to 2.7 volts. Six cells in series (for example) can be operated at any voltage up to 16.2 volts (6 x 2.7V = 16.2V).

Connect the ultracapacitor to the power supply (having pre-set the current and voltage limits).

Cooling air may be required to keep the ultracapacitor within operating temperature limits, depending on the test current and duration.

Connect the voltage and current measuring/recording devices.

Charge

With the power supply pre-set, and the ultracapacitor connected, turn the supply output ON.

Charge the ultracapacitor at the appropriate current to the appropriate voltage.

Discharge

Note: If using a separate programmable load instead of an integrated bi-directional power supply, disconnect the charging power supply prior to discharging. (Don't simply turn it off or change its set points, as many supplies will sink current when not regulating.)

Set the load to the appropriate constant current, and discharge to 0.1V, or as low as the load can be controlled.

IMMEDIATELY remove the load once the minimum voltage is reached, allowing the device's voltage to "bounce" back.

(The discharge can actually be stopped at any voltage. Depending on equipment, some units can be discharged to 0.1V, and others discharged to ½ of the initial voltage. Values of capacitance will be slightly higher when discharged to ½ initial voltage rather than 0.1V.)

Measure the following parameters: (reference figure 1)

V_w = initial working voltage V_{min} = minimum voltage under load

I_d = discharge current V_f = voltage 5 seconds after removal of load.

t_d = time to discharge from initial voltage to minimum voltage

Capacitance calculation:

$$\text{Capacitance} = (I_d * t_d)/(V_w - V_f) = (I_d * t_d)/V_d$$

(This change in voltage ($V_w - V_f$) is used because it eliminates the voltage drop due to the equivalent series resistance)

Equivalent Series Resistance (at "DC") calculation:

$$ESR = (V_f - V_{min})/I_d$$

(An LCR meter or bridge can be used to measure ESR at higher frequencies. The ESR at frequencies up to 100Hz will typically be 50-60% of the "DC" ESR. The capacitance will be much lower, due to the structure of the electrode.)

(Note that calculations for Capacitance and Resistance can also be done on the charge)

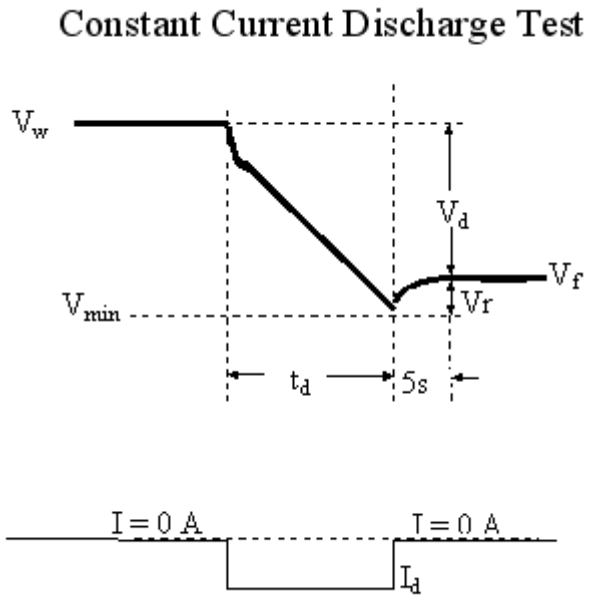

Figure 1: Representative measurement points for constant current test

Safety Considerations

As in all electrical testing, you as the investigator should take appropriate cautions in the design and execution of the test. Proper precautions for the appropriate voltage should be observed. Any interconnections should be sized for the maximum anticipated current, and insulated for the appropriate voltage. If repeated testing will be performed, cooling air may be required to keep the test unit within its operating temperature range.