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VOLTAGE DELAY AND COMPLEX IMPEDANCE CHARACTERISTICS OF A HIGH-RATE LITHIUM/SILVER–VANADIUM OXIDE MULTIPLATE BATTERY (EXTENDED ABSTRACT)

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A high-rate, multiplate lithium/organic electrolyte/silver–vanadium oxide system has been developed to power implantable cardiac defibrillators [1]. Room temperature voltage delay and complex impedance analyses have been completed on five rectangular cells (dimensions: 13.5 mm × 52 mm × 21 mm; external volume: 14.6 cm^3; theoretical capacity: 3.0 A h) at different depths of discharge.

After manufacture, 2% of each cell's theoretical capacity was extracted and the cells were allowed to rest for one month. A 2.0 A, 10 s pulse was then applied to record voltage delay. Figure 1 presents an example of the recorded voltage response. Initial open circuit voltages ranged from 3240 to 3260 mV; initial 2.0 A voltages ranged from 2355 to 2410 mV; initial 2.0 A voltage drops ranged from 850 to 905 mV; final 2.0 A voltages ranged from 2500 to 2550 mV.

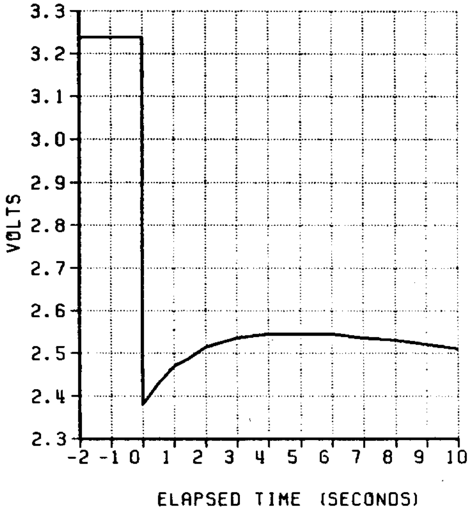

Fig. 1. Voltage delay during a 10 s 2.0 A pulse.

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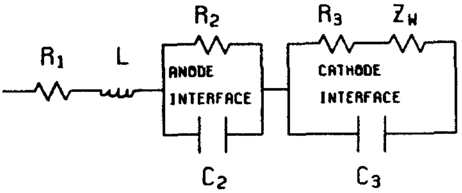

$Z_{TOT} = Z_{R_1} + Z_L + Z_2 + Z_3$
$= \text{Real } Z_{TOT} + (J) \text{ Imag } Z_{TOT}$

Fig. 2. Equivalent circuit model for complex impedance response:
$Z_{R_1} = R_1$
$Z_L = J\omega L$
$Z_2 = ((R_2)^{-1} + (J\omega)^{\eta_2} C_2)^{-1}$
$Z_3 = ((R_3 + Z_w)^{-1} + (J\omega)^{\eta_3} C_3)^{-1}$
where
$J = \sqrt{-1}$
$\omega = 2\pi F$ = Angular frequency
R_1, R_2, R_3 = Resistive components (Ω)
L = Inductive component (H)
C_1, C_2, C_3 = Capacitive components (F)
Z_w = Warburg impedance contribution = $K(1 - J)/\sqrt{\omega}$
K = Warburg coefficient
η_2, η_3 = $1 - \theta_{2,3}/90.0$
θ_2, θ_3 = Angles of deviation from ideal symmetry about the —Imag $Z = 0$ axis (degrees).

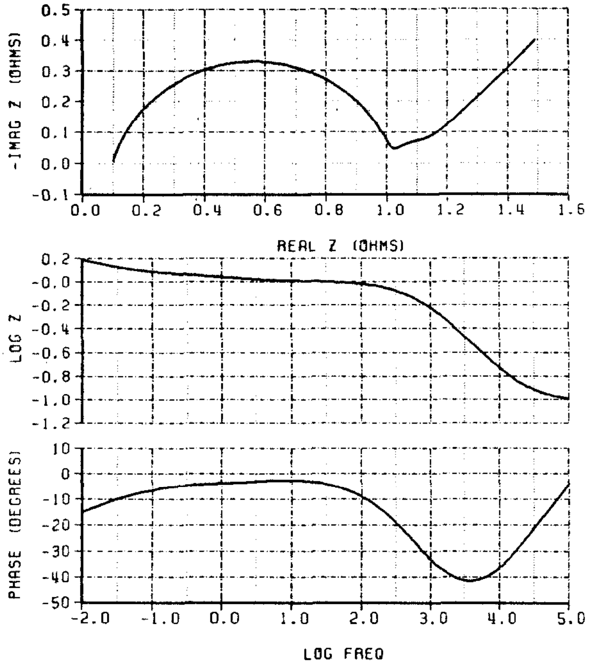

Fig. 3. Complex impedance results before pulse discharge (av. of 4 cells). $R_1 = 0.09$ Ω, $R_2 = 0.94$ Ω, $R_3 = 0.09$ Ω; $K = 0.099$, $L = 0.0212$ μH, $C_2 = 0.0013$ F, $C_3 = 0.7814$ F.

During the one month storage period, complex impedance responses were obtained on four cells over the frequency range 0.01 - 100 000 Hertz using a PAR Model 368 a.c. impedance measurement system. Results were then integrated with an equivalent circuit model (Fig. 2) developed from the work of Mauger *et al.* [2], and circuit parameters were obtained using the relationships shown below.

Figure 3 presents the Nyquist and Bode graphs for the average of the modeled complex impedance responses along with the resulting circuit parameters.

The test cells then went through a regime of partial discharge (using 2.0 A, 10 s pulses with four pulses per train, 15 s of rest between pulses, and 30 min of rest between pulse trains), storage, complex impedance and voltage delay testing until they reached end-of-life (1.7 V under the 2.0 A pulse load). Voltage delay and complex impedance analyses were completed at each depth of discharge, and trends in the initial 2.0 A voltages and the complex impedance equivalent circuit parameters were noted as functions of depth of discharge.

References

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