# THERMAL ASPECTS OF LITHIUM ION CELLS

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# OBJECTIVE

Develop thermal model of Li-Ion cells in terms of heat generation, thermal mass, and thermal resistance. Intended for incorporation into battery model.

# APPROACH

Heat Generation:

-Estimate rates with semi-theoretical model

-Check accuracy with efficiency measurements

Thermal Mass:

-Compute from component weights and specific heats

Thermal Resistance:

-Compute from component dimensions & conductivities

# METHOD FOR ESTIMATING HEAT GENERATION RATE

$Q = I (V_{oc} - V)$

where:

| | | |
|---|---|---|
| Q | = | instantaneous cell heat generation at given current (I), temperature (T), and state-of-charge (SOC) |
| I | = | Cell current , amps |
| $V_{oc}$ | = | open circuit voltage (V) at given T, and SOC, volts |
| V | = | operating voltage at given I, T, and SOC, volts |

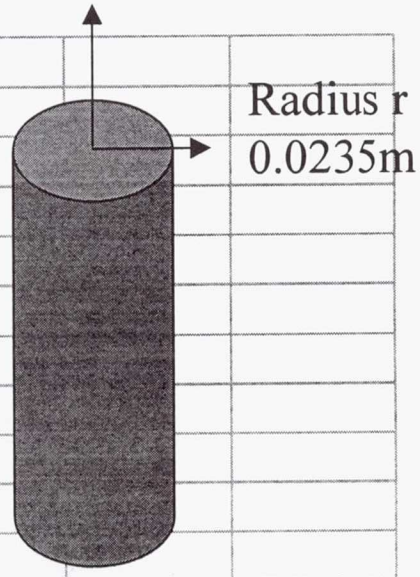
## INPUT DATA OBTAINED EXPERIMENTALLY

$V_{oc}$ as a function of SOC and T

V as a function of SOC, I, and T

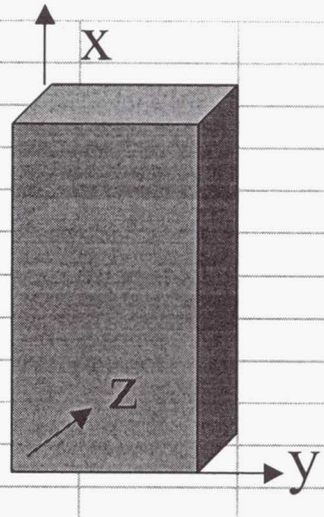
# Properties of components

| Cylindrical lithium battery | | | | | | | |
|---|---|---|---|---|---|---|---|
| length, Lx or height | 0.192 | m | | | | | |
| diameter | 0.047 | m | | | | | |
| **Conductivities** | | | | | | | |
| kpara along x | 57 | W/mK | | | | | |
| keff=kz in the normal directio | 1.73 | W/mK | | | | | |
| **RESISTANCES** | | | | | | | |
| Rperp_whole cell, Rz | 1.82 | K/W | | | | | |
| Rx, along length | 1.9425 | K/W | | | | | |
| Ral_tab | 77.7 | K/W | | | | | |
| **mass and thermal properties** | | | | | | | |
| | mass,kg | cp,J/kg K | density,kg/m3 | k, W/mK | mass*cp, J/oK | | |
| can stainless | 0.126 | 502.8 | 7800 | 16.3 | 63.3528 | | |
| A_coating | 0.112 | 838 | 1800 | 5 | 93.856 | | |
| C_coating | 0.318 | 838 | 1800 | 5 | 266.484 | | |
| Copper substrate | 0.064 | 385.48 | 8900 | 381.29 | 24.67072 | | |
| Al substrate | 0.043 | 905.04 | 2700 | 201.12 | 38.91672 | | |
| separator | 0.027 | 1676 | 900 | 0.2 | 45.252 | | |
| electrolyte | 0.227 | 2514 | 1200 | 0.1676 | 570.678 | | |
| **TOTAL** | 0.917 | | | | **1103.2** | **thermal mass** | |



# Component Properties

| Prismatic lithium cell | | | | | | |
|---|---|---|---|---|---|---|
| length, Lx | 0.118 | m | | | | |
| width, Ly | 0.091 | m | | | | |
| thickness,Lz | 0.027 | m | | | | |
| area | 0.010738 | m2 | | | | |
| **Conductivities** | | | | | | |
| kpara along x or y | 26.69 | W/mK | | | | |
| keff=kz in the normal directio | 1.848 | W/mK | | | | |
| **RESISTANCES** | | | | | | |
| Rperp_whole cell, Rz | 1.379 | K/W | | | | |
| Rx, along length | 1.778 | K/W | | | | |
| Ry, along width | 1.049 | K/W | | | | |
| Ral_tab | 21.14 | K/W | | | | |
| R_all_tabs | 0.128 | K/W | | | | |
| **mass and thermal properties** | | | | | | |
| | mass,kg | cp,J/kg K | density,kg/m3 | k, W/mK | mass*cp J/K | |
| can stainless | 0.169 | 502.8 | 7800 | 16.3 | 84.9732 | |
| A_coating | 0.184 | 838 | 1800 | 5 | 154.192 | |
| C_coating | 0.228 | 838 | 1800 | 5 | 191.064 | |
| Copper substrate | 0.077 | 385.48 | 8900 | 381.29 | 29.68196 | |
| Al substrate | 0.043 | 905.04 | 2700 | 201.12 | 38.91672 | |
| separator | 0.02 | 1676 | 900 | 0.2 | 33.52 | |
| electrolyte | 0.146 | 2514 | 1200 | 0.1676 | 367.044 | |
| **TOTAL** | 0.867 | | | | **899.39188** | **thermal mass** |



# CONCLUSIONS

# 25 AH Li-ION CELL

## HEAT GENERATION

- Developed heat generation rate model as function of I, V, & SOC
- Heat proportional to I for C & D
- Heat increases with decrease in T
- Heat is relatively independent of SOC
- Typical Heat @ 5A, 0°C, & 50%DOD: 1.5W(D), 0.5W(C)
- Support for model shown by agreement of predicted heat (by integrating calculated values) and indirectly measured heat (from electrical efficiency data) for a complete cycle

# CONCLUSIONS

## (cont'd)

## THERMAL MASS

Prismatic Cell.....900 J/°K

Cylindrical Cell.....1103 J/°K

## THERMAL RESISTANCE

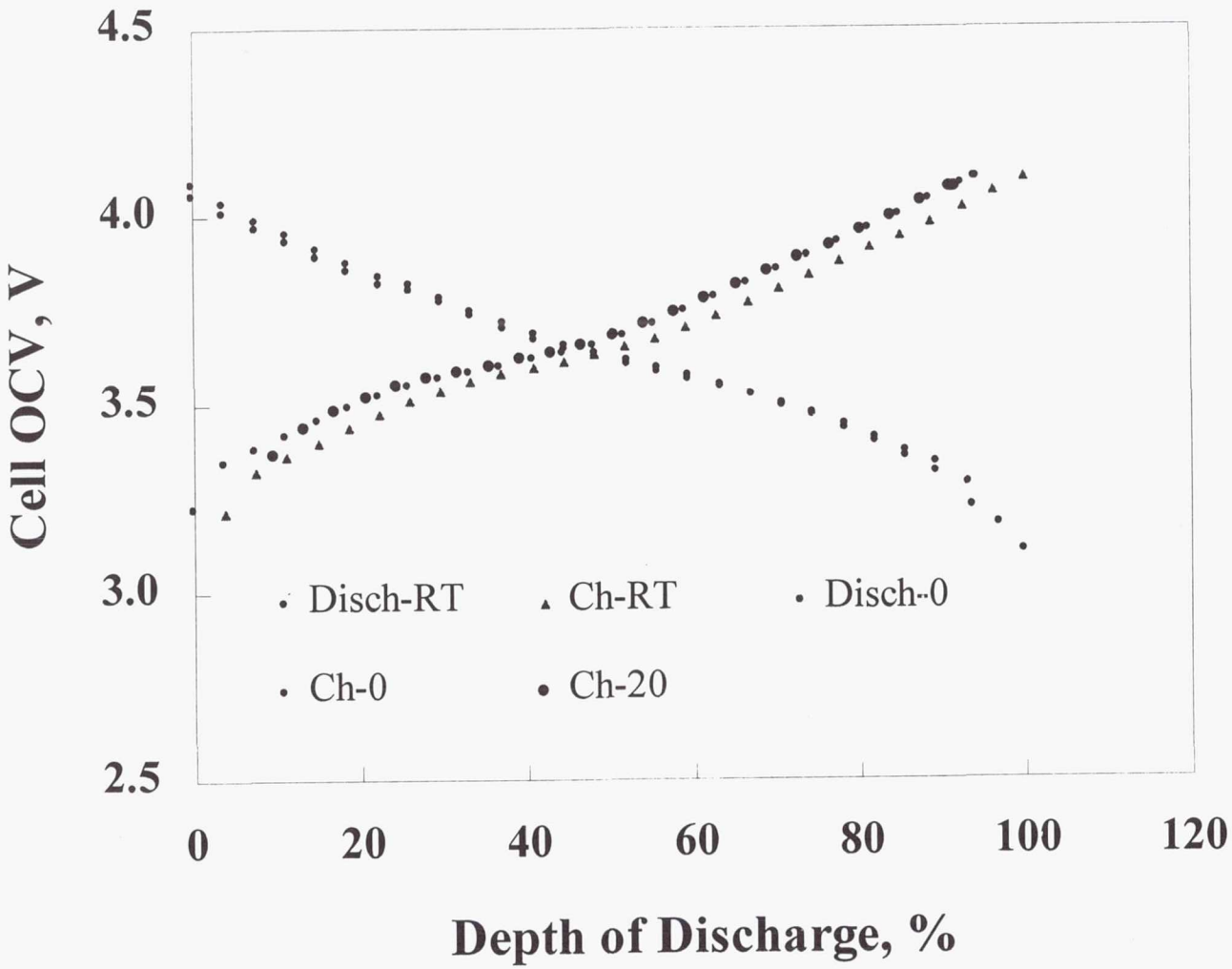
Prismatic (Perpendicular to plates).....1.4°K/W

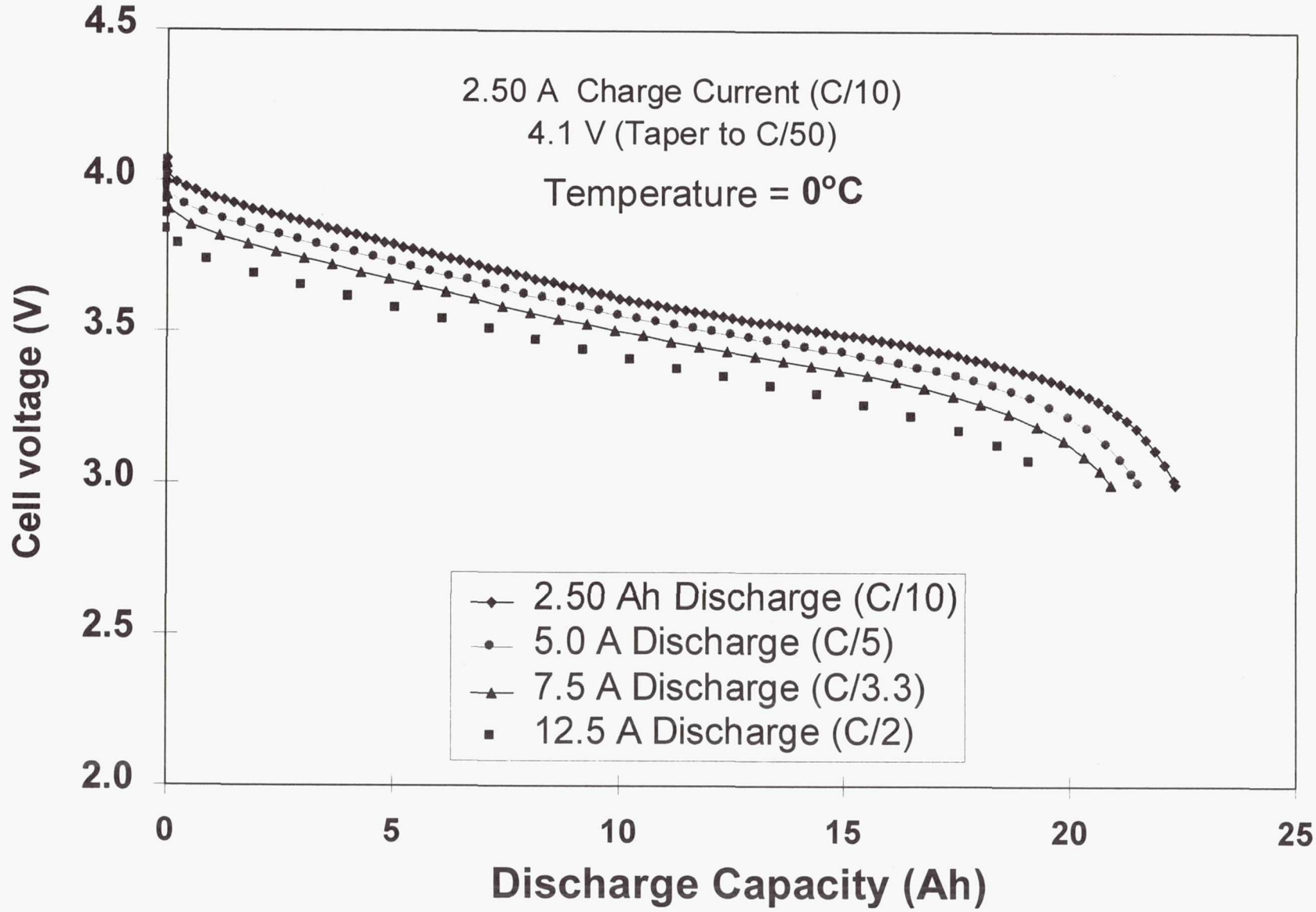
Prismatic (Parallel to plates, ).....1.0-1.8 °K/W

Cylindrical ( Perpendicular to plates, radial).....1.8°K/W

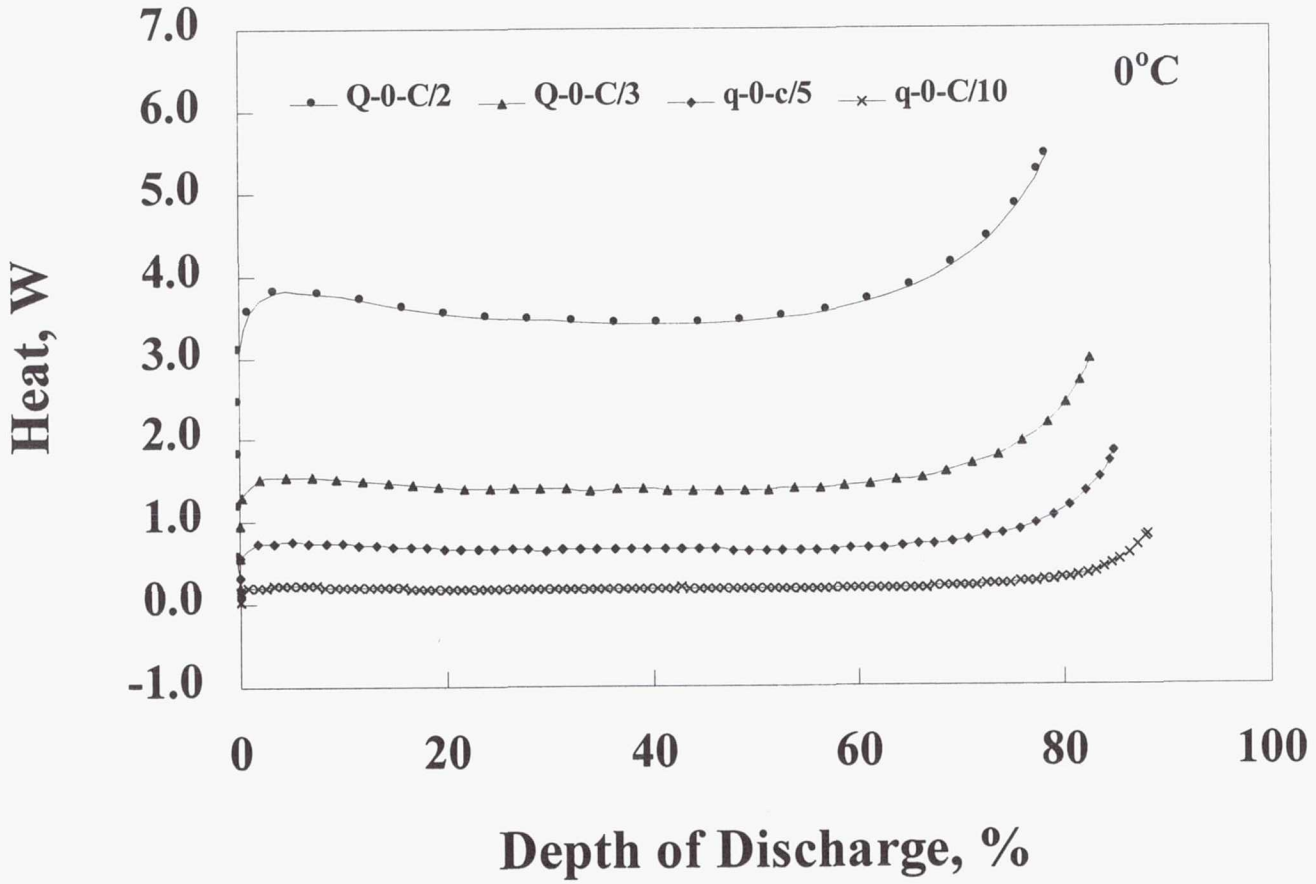
Cylindrical (Parallel to plates, along height).....1.9°K/W

# Open-circuit Curves of Prismatic Li Ion cells

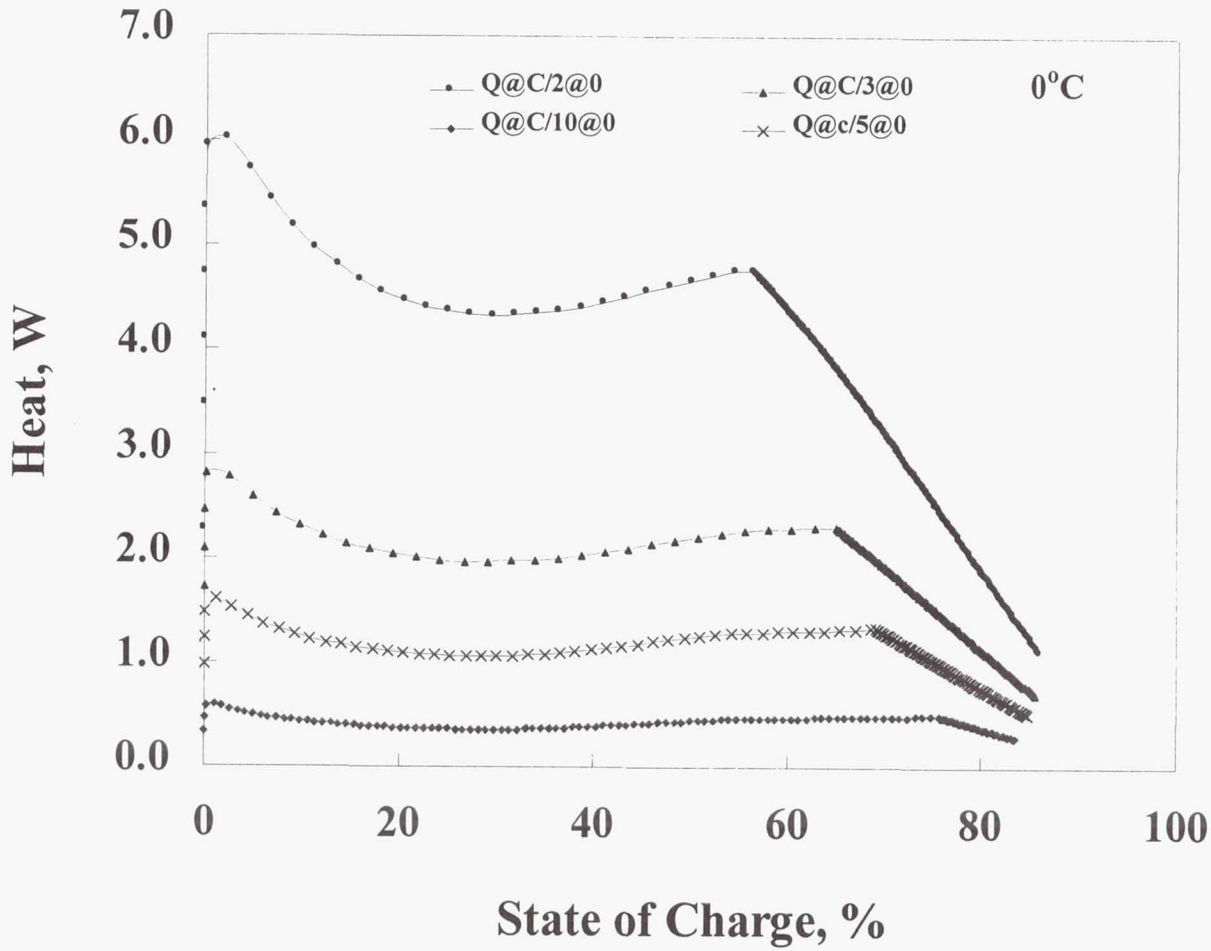



2.50 A Charge Current (C/10)
4.1 V (Taper to C/50)
Temperature = 0°C
Cell voltage (V)
4.5
4.0
3.5
3.0
2.5
2.0
0
5
10
15
20
25
Discharge Capacity (Ah)
2.50 Ah Discharge (C/10)
5.0 A Discharge (C/5)
7.5 A Discharge (C/3.3)
12.5 A Discharge (C/2)

# Heat Evolution During Discharge of Prismatic Cells



# Heat Evolution During Charge of Prismatic Cells



# Heat Evolution During Discharge of Prismatic Cells