# Battery Packaging Considerations for Prismatic Lithium Ion Aerospace Cells

***J.W. Baker*, B.J. Stein, P.M. Shah, N.D. Isaacs**

Mine Safety Appliances Company

# INTRODUCTION

# PURPOSE OF PRESENTATION

Provide battery manufacturers data needed for designing battery hardware necessary to withstand the forces exerted by MSA manufactured aerospace lithium ion cells

# PRISMATIC LITHIUM ION CELLS

## Prismatic (Stacked) vs. Cylindrical

- More Efficient Packing Density
- Simpler Heat Sink Design
- Uniform Electrode Stack Force (long cycle life)

## Battery Considerations for Prismatic Cells

- End Plate Design must Account for Forces Exerted by Cells

# FORCE ENCOUNTERED EXTERNAL TO THE CELL

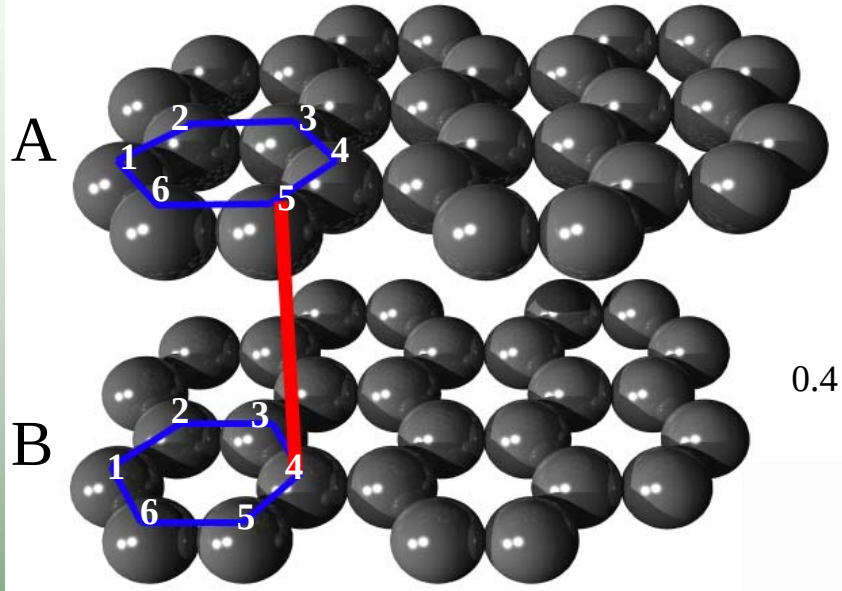
Charge and Discharge Causes Structural Changes Within the Electrode Materials

# INTRODUCTION

- **ORIGIN OF FORCES**
- **POUCH CELL STUDIES**
  - Thickness Measurements
  - Force Measurements
  - Structural Changes in Active Materials
- **FORCES EXERTED BY LARGE CELLS**
  - 50 Ah Aerospace Cells
  - 10 Ah Aerospace Cells
- **SUMMARY**

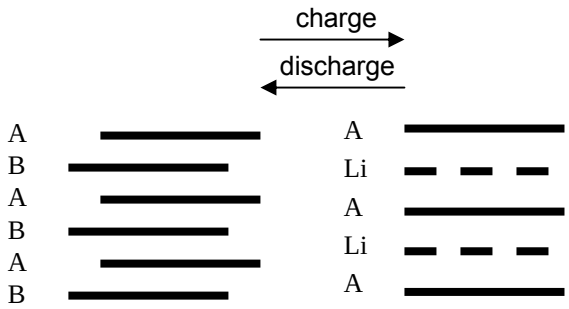
# ORIGIN OF FORCES

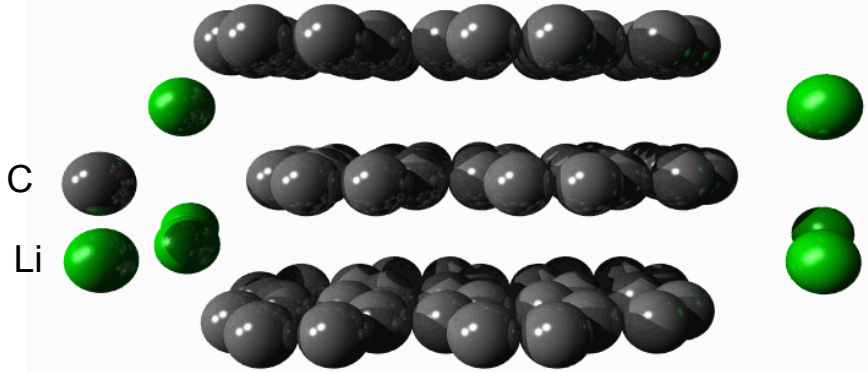
# GRAPHITE CRYSTAL STRUCTURE




On charge, Li moves into the crystal causing layer shift and expansion. Discharge moves Li out of the structure causing layer shifting and contraction.

0.4 Å expansion between layers or 0.8 Å “c” lattice

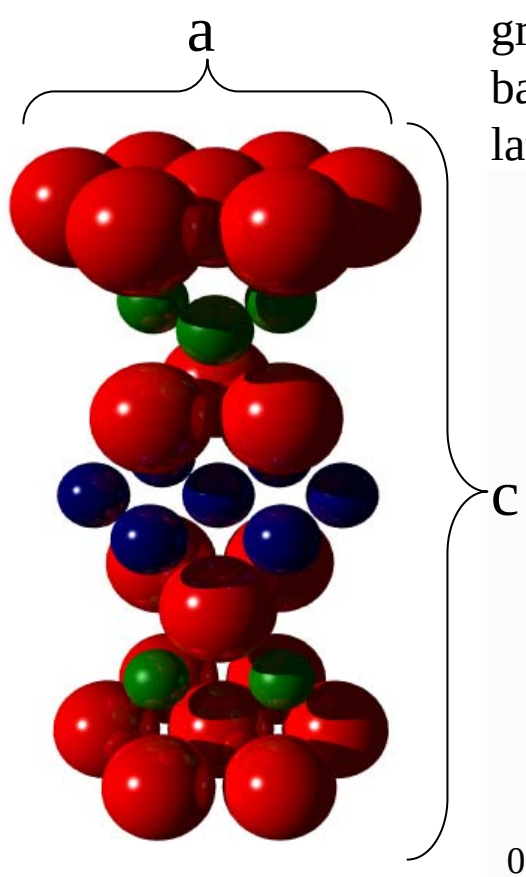


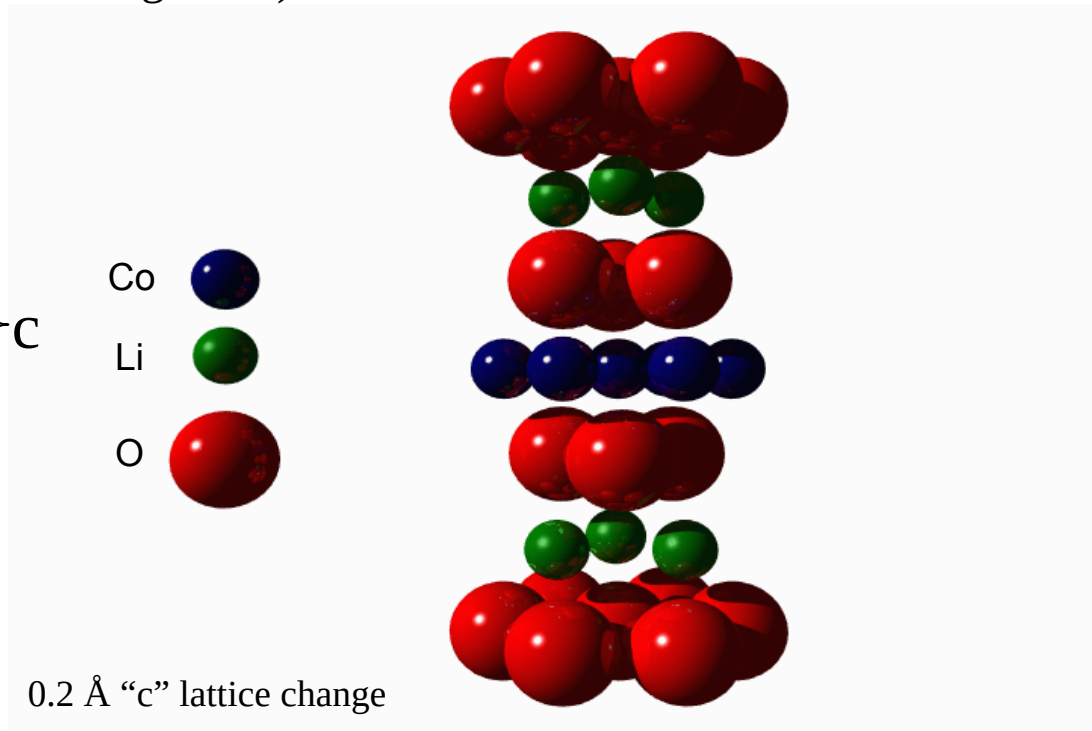

M. Winter; J. Bessenhard; Lithiated Carbons. In *Handbook of Battery Materials*, Jürgen O. Besenhard, Ed.; Wiley-VCH: New York, 1999, 387.

# $Li_xCoO_2$ CRYSTAL STRUCTURE

On charge, Li moves out of crystal causing “c” lattice growth (decrease in “a” lattice). Discharge moves Li back into crystal causing “c” lattice contraction (“a” lattice growth).




Distorted Hexagonal Structure




J. N. Reimer and J. R. Dahn, *J. Electrochem. Soc.*, **139**, 2091 (1992).

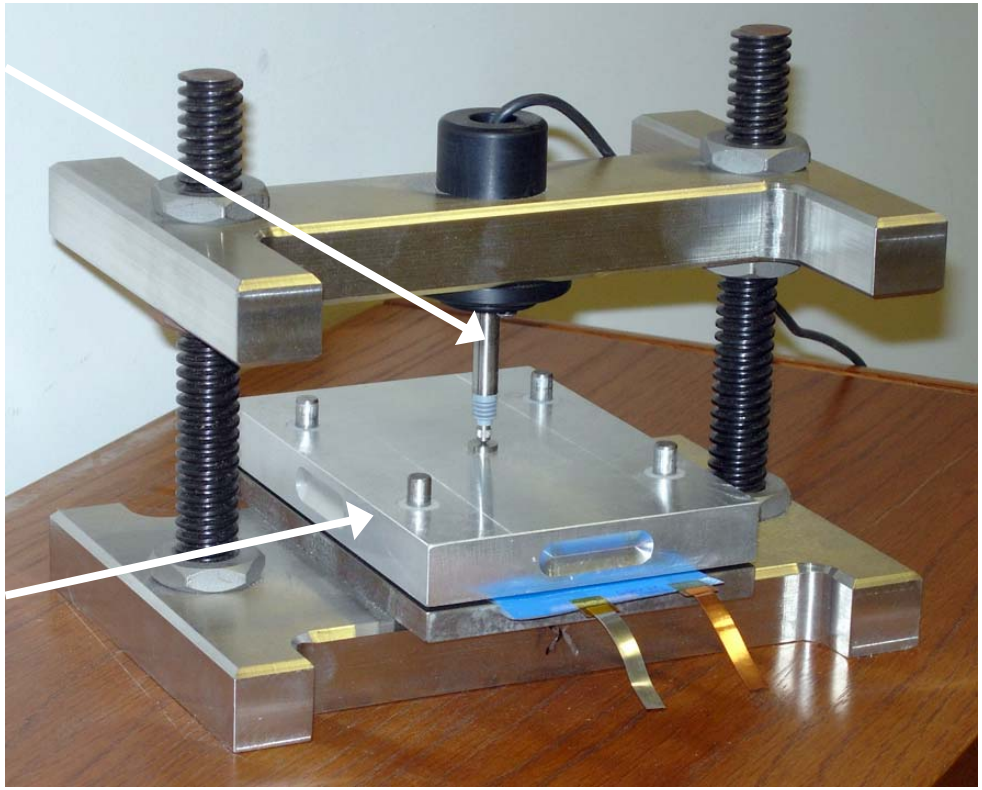
G. G. Amatucci, J. M. Tarascon, and L. C. Klein, *J. Electrochem. Soc.*, **143**, 1114 (1996).

# POUCH CELL STUDIES

# MEASUREMENT TECHNIQUES

Thickness Gage

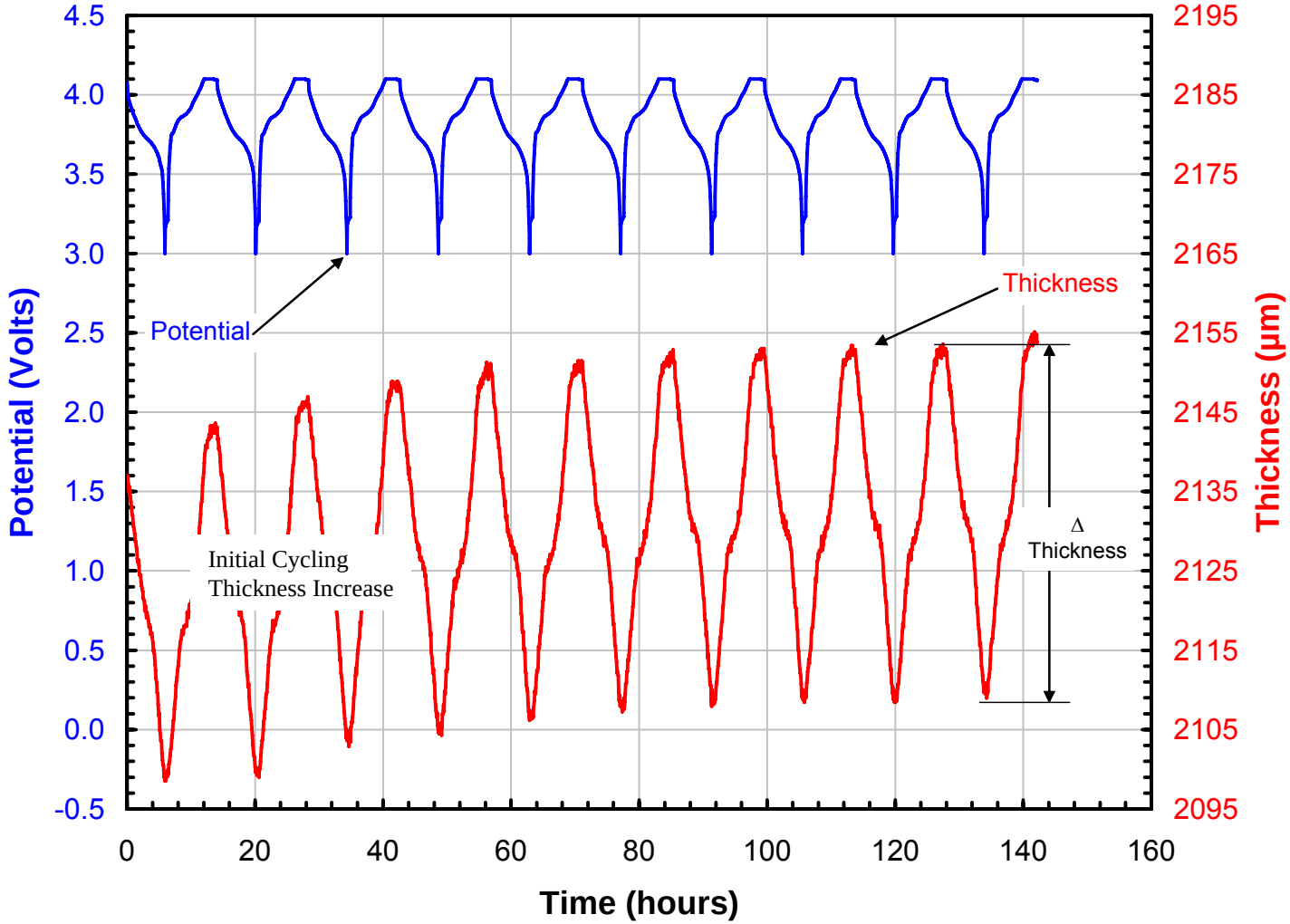
(Substitute Load Cell for Force Measurements)



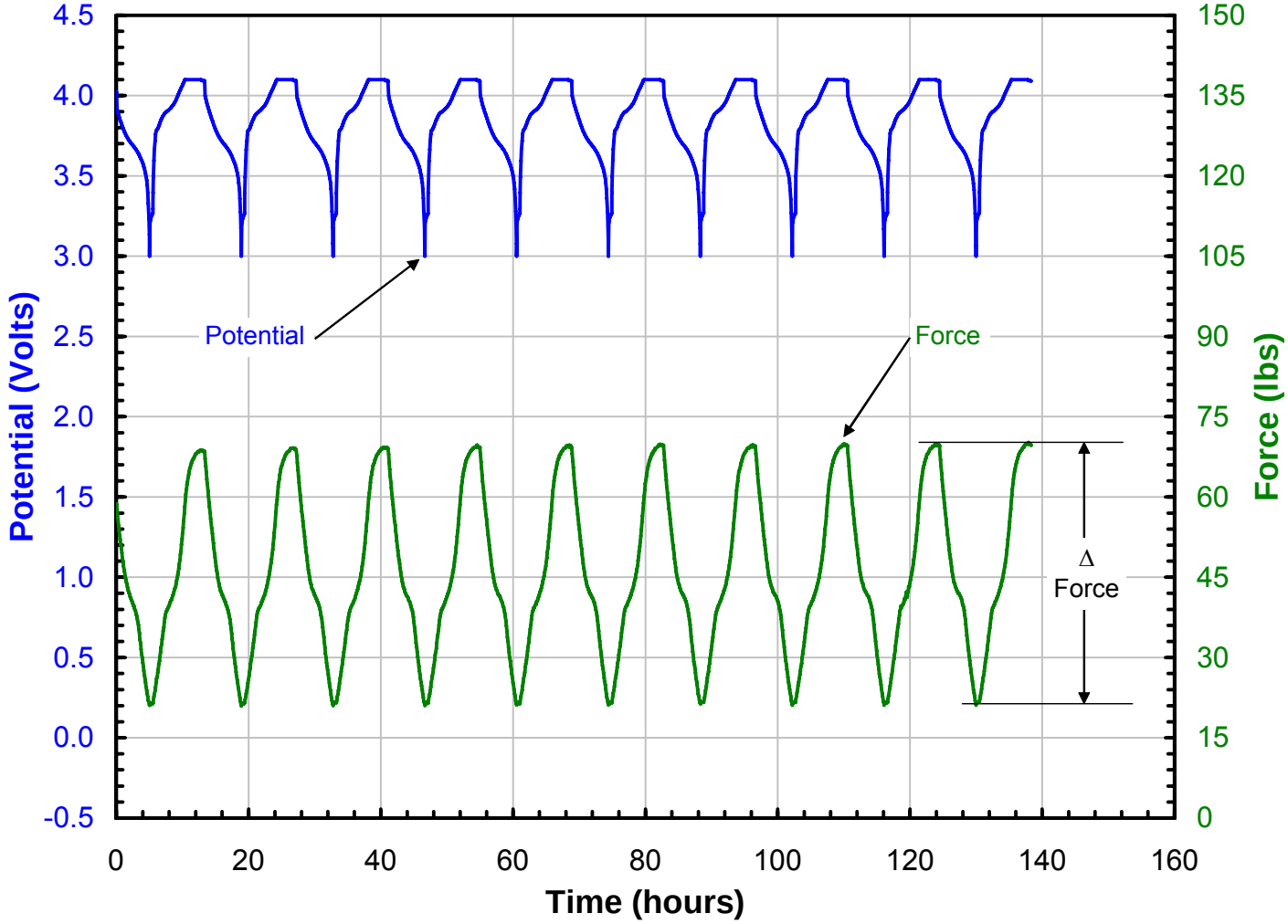
Constant Force on Cell

(Fixed Distance allows Variable Force for Force Measurements)

# THICKNESS MEASUREMENTS



# FORCE MEASUREMENTS



# RESULTS

## Δ Thickness

Thickness Change Between Charge and Discharge (µm)

| Positive Active Material | Negative Active Material: 10 µm Graphitic Carbon | Negative Active Material: 25 µm Graphitic Carbon |
|---|---|---|
| 20 µm $Li_xCoO_2$ | 32 | 44 |
| 10 µm $Li_xCoO_2$ | 30 | 42 |

## Δ Force

Force Change Between Charge and Discharge (lb)

| Positive Active Material | Negative Active Material: 10 µm Graphitic Carbon | Negative Active Material: 25 µm Graphitic Carbon |
|---|---|---|
| 20 µm $Li_xCoO_2$ | 57 | 50 |
| 10 µm $Li_xCoO_2$ | 15 | 17 |

Change in Thickness Occurs with Change in Positive but Not with Change in Negative

Force Occurs with Change in Negative but Not with Change in Positive

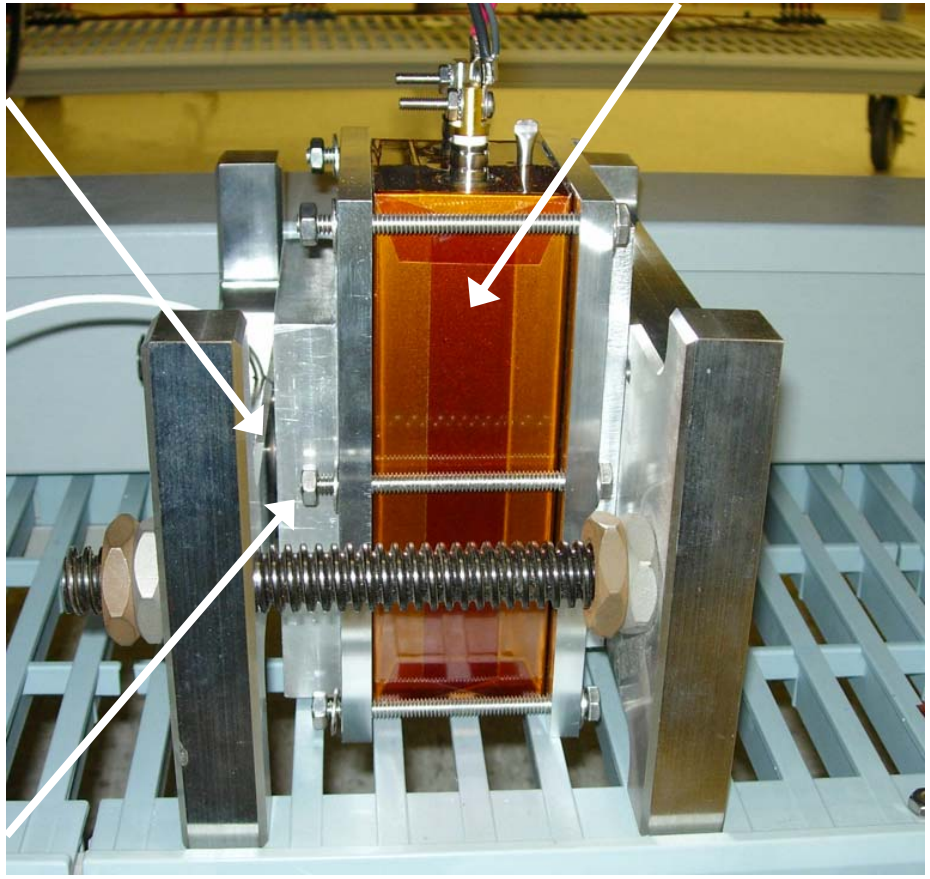
Caution: Single Cell Results – Not a Statistical Sampling

# FORCES EXERTED BY LARGE CELLS

# MEASUREMENT TECHNIQUE

Load Cell
(Force lb)
Pushes Against
Cell Broad Face

Cell



Force Calibrated
at 200 lb and 1800 lb

Calibration Force Gage
Accurate to ± 20 lb

Tighten Fixture to
Register ~10 lb, then
Loosen End Plate Nuts

- **LARGE CELL FORCE MEASUREMENTS**
  - Charge Cells in 10 Ah Increments

    Constant Current (x A) to 4.0 V,
    Taper to y A

    50 Ah Cell: x = 2.9, y = 0.5

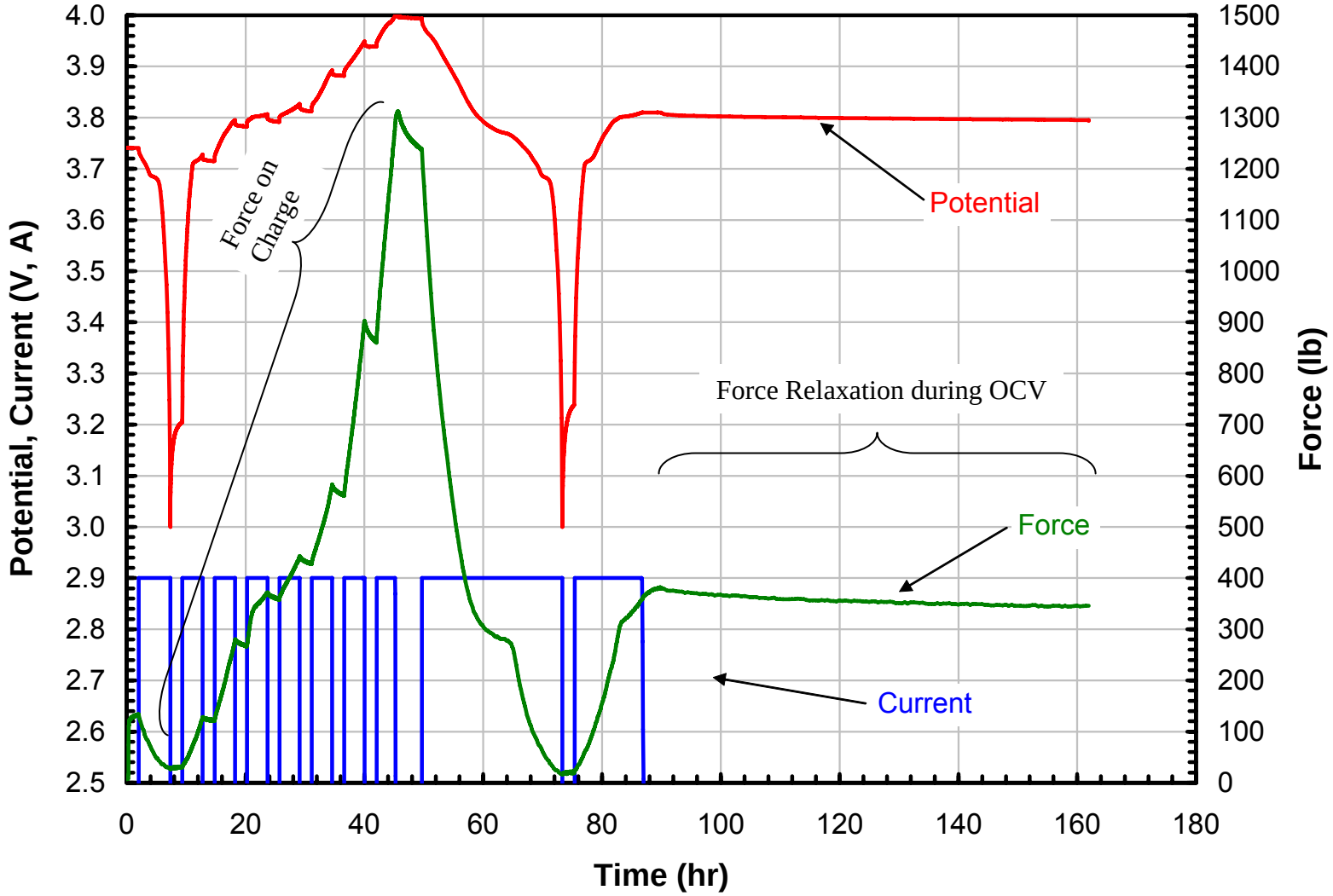
    10 Ah Cell: x = 2.0, y = 0.1
  - Evaluate Force Relaxation

    Discharge to 3.0 V

    Charge to 3.81 V

    OCV Stand for 72 h

# 50 Ah CELL FORCE MEASUREMENTS



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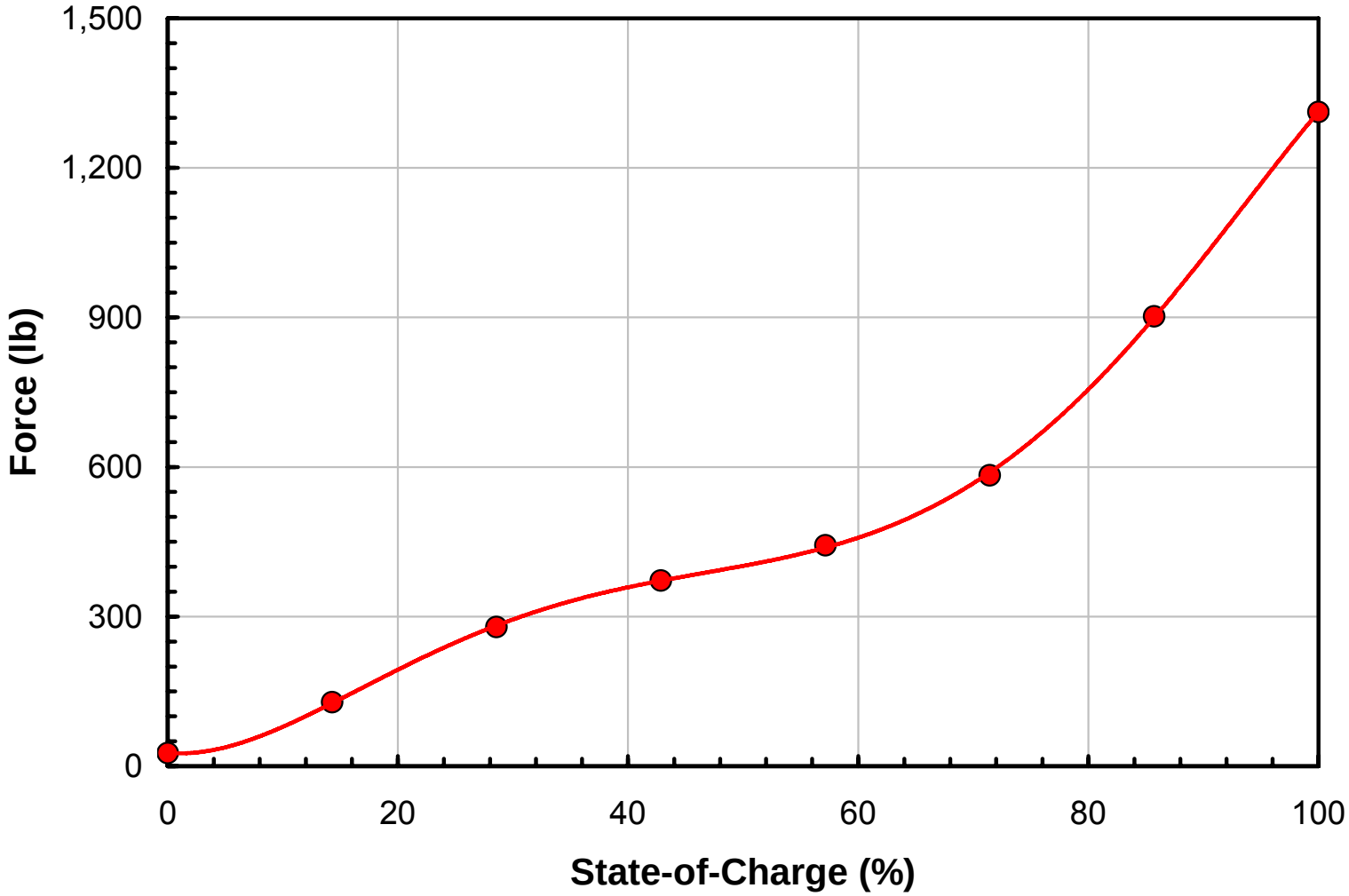

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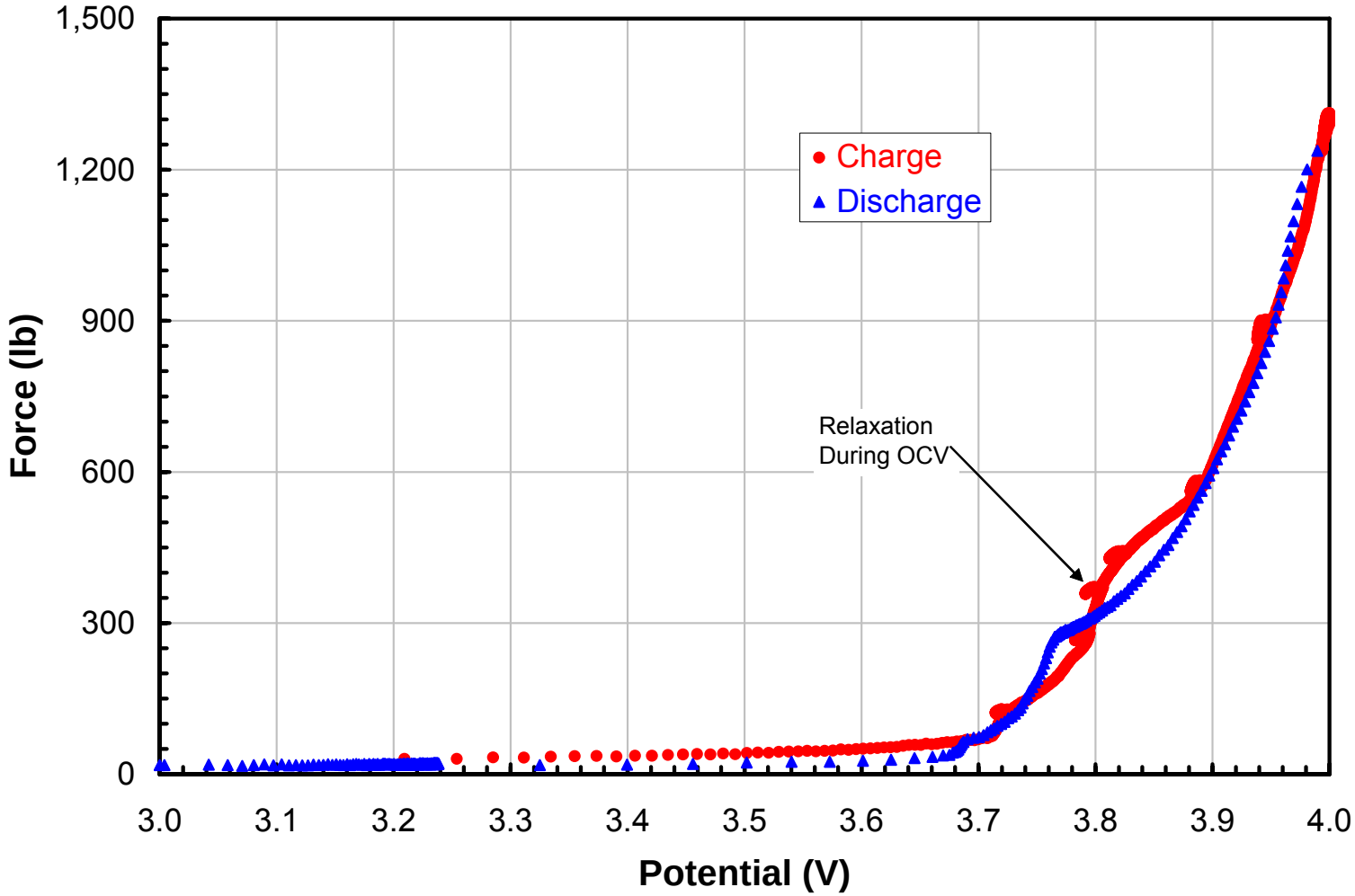
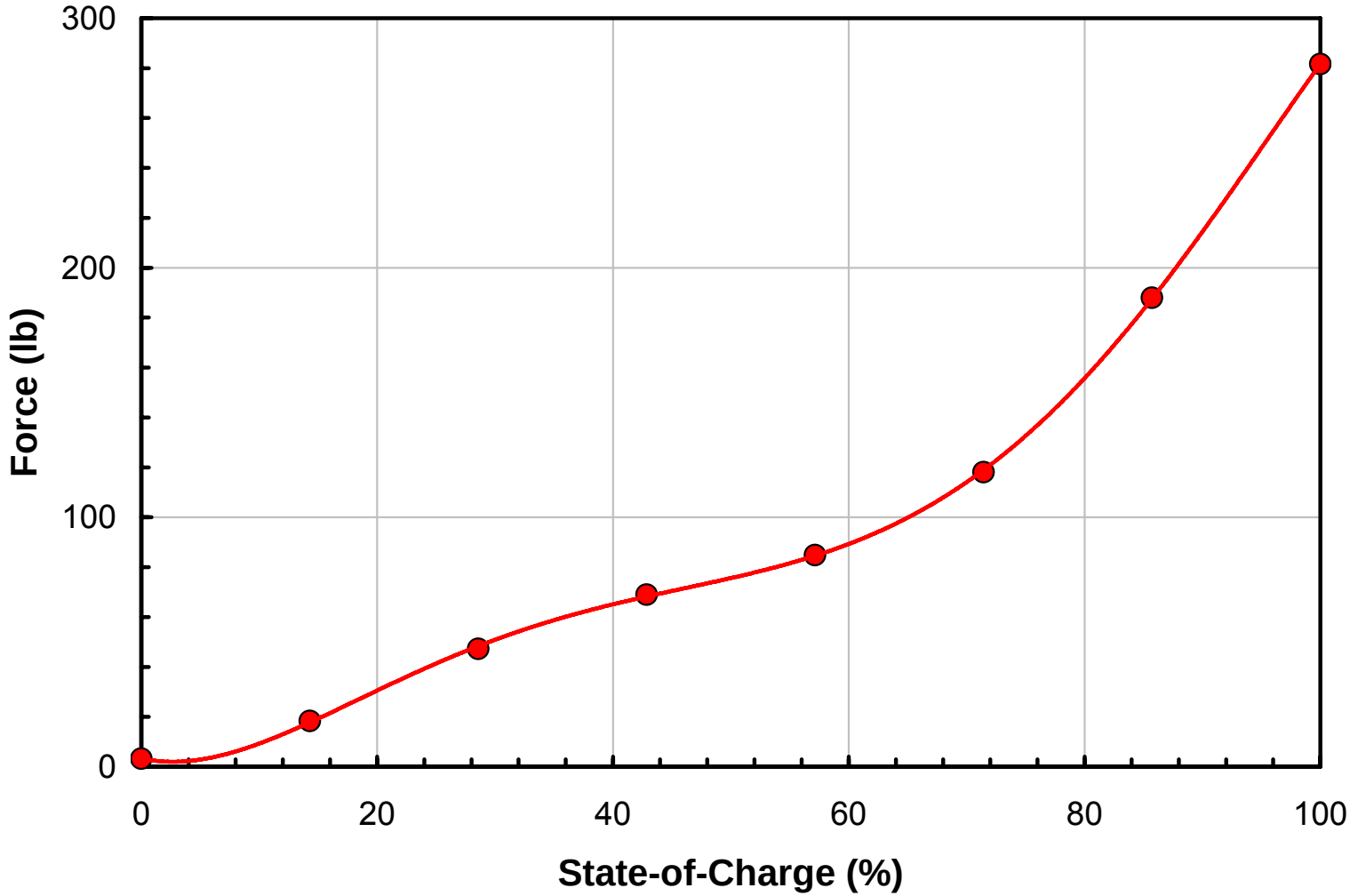


# 10 Ah CELL FORCE MEASUREMENTS



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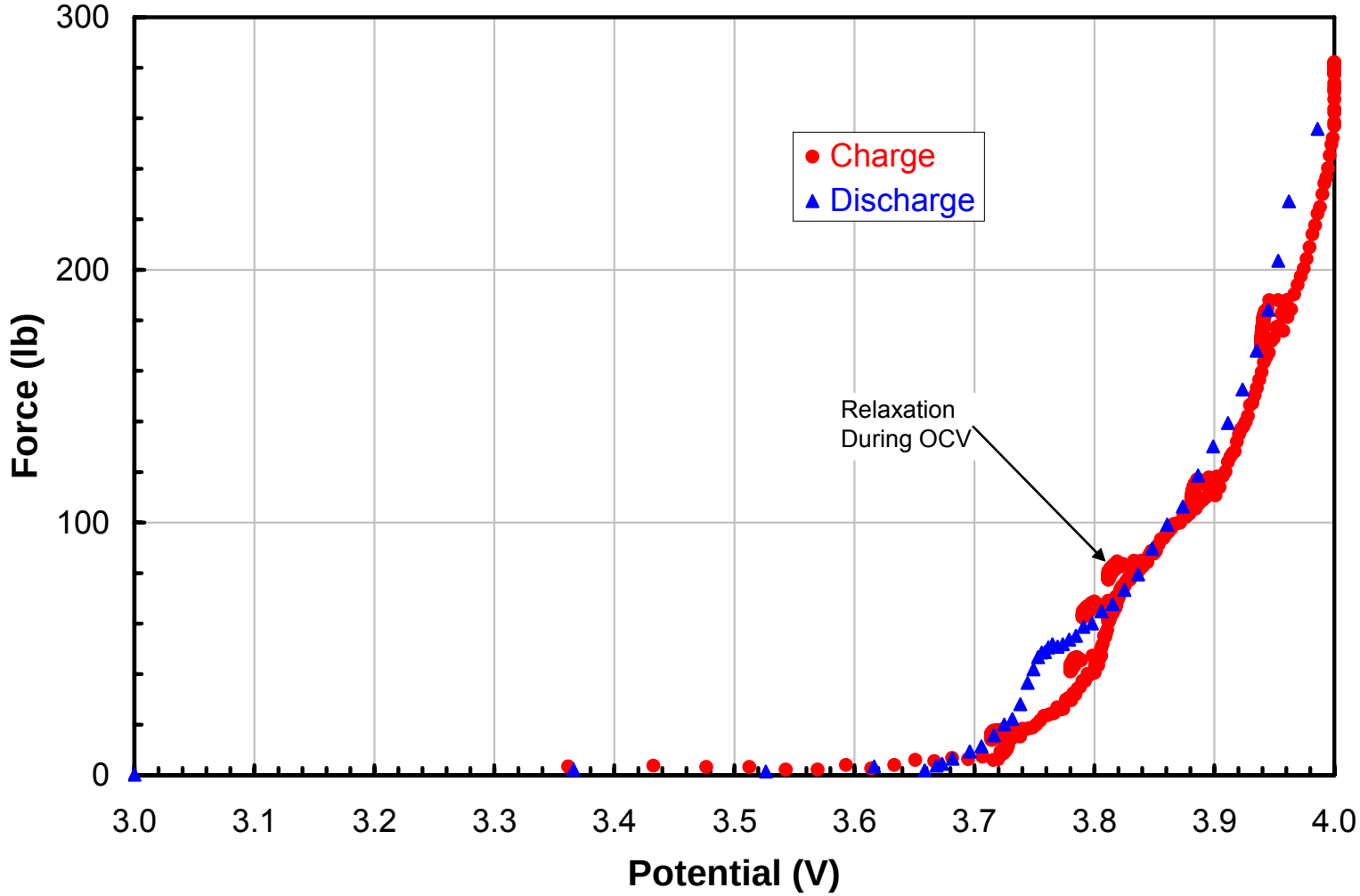
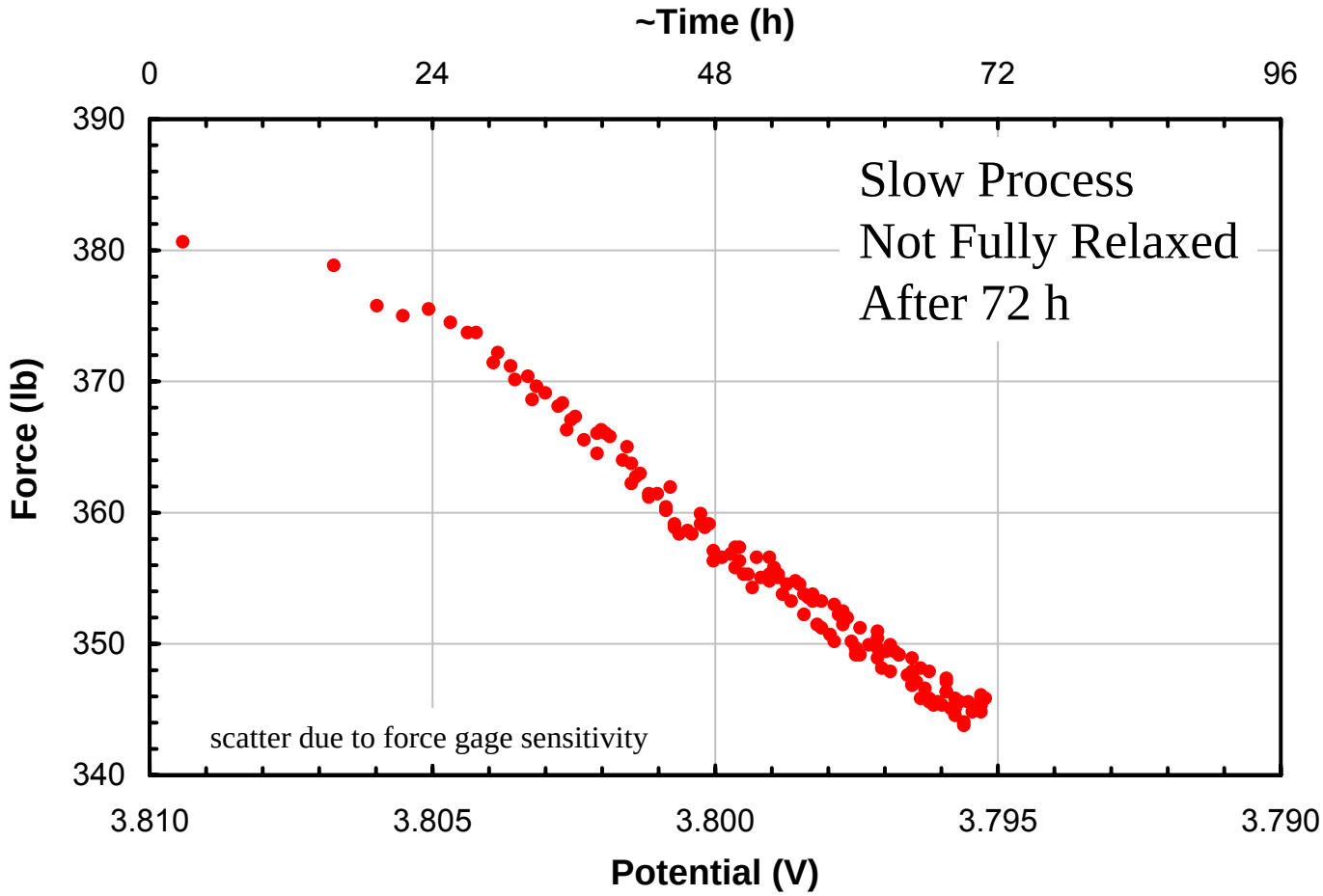


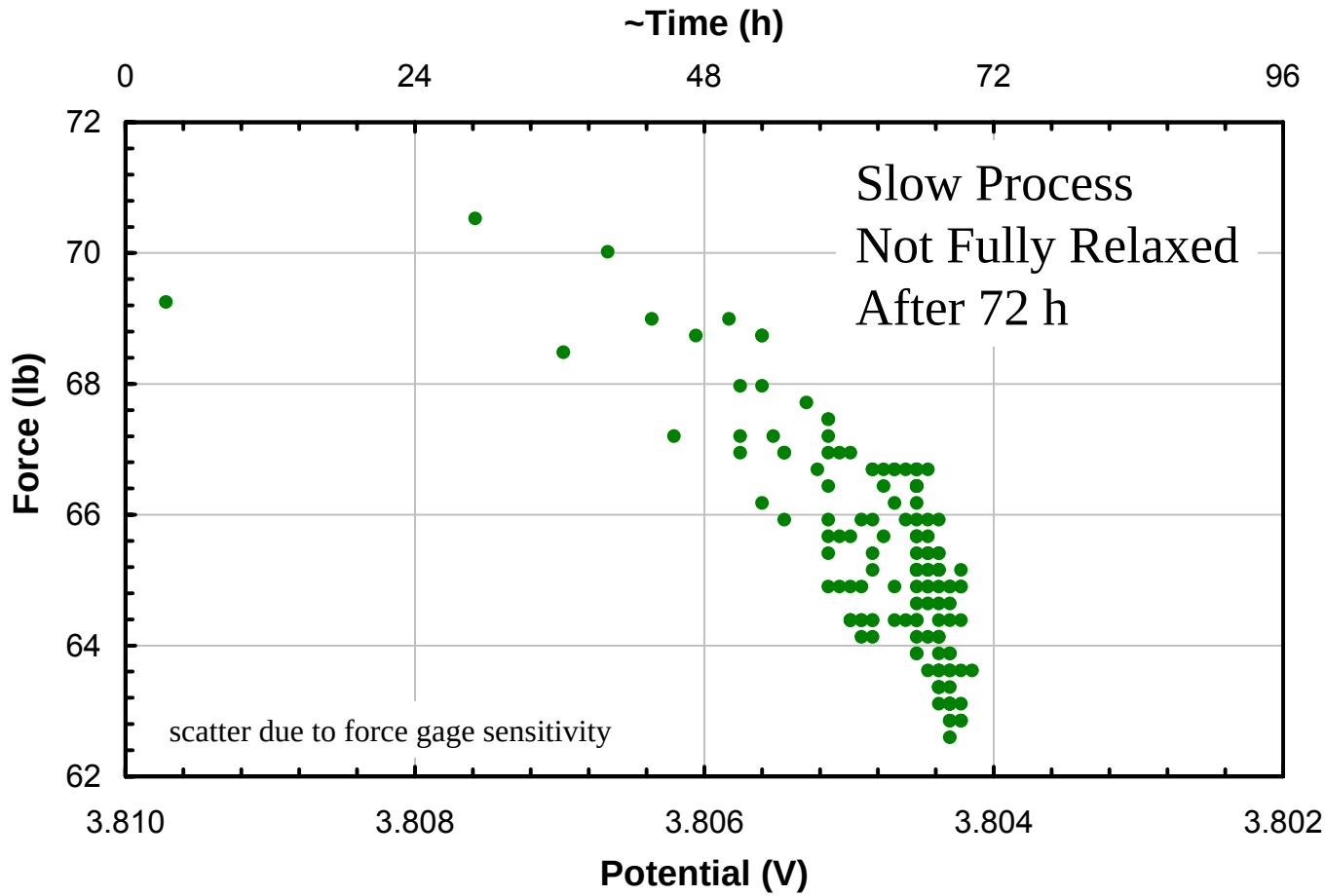
# FORCE RELAXATION OCV STAND

## 50 Ah Cell at Charged to 3.81 V



# FORCE RELAXATION OCV STAND

## 10 Ah Cell at Charged to 3.81 V



# • FORCE RELAXATION OCV STAND

- Relaxation of Force

  Cells had different self-discharge characteristics but similar relaxation of force

  - 50 Ah was 91% of Initial after 72 h
  - 10 Ah was 92% of Initial after 72 h

- Distribution of Li in Crystal lattice

  Li slowly diffuses through crystal lattice independent of self-discharge allowing equilibration/relaxation of force exerted

# SUMMARY

## SUMMARY

- **EXERTED FORCE**
  - Maximum Force (4.0 V Charge)

    50 Ah: 1300 lb

    10 Ah: 300 lb

    Equivalent forces based on total electrode plate surface area (0.3 lb/in$^2$ of active electrochemical area)

    Higher charge potential would result in higher forces

- **BATTERY CONSIDERATIONS**
  - Forces Originate Mainly in Positive Electrode
  - Need For Appropriate Strength End Plate Design
  - Best to Assemble Battery with Cells Near Fully Discharged Condition (3.0 V)

# ACKNOWLEGEMENTS

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