1997 NASA BATTERY WORKSHOP

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HUNTSVILLE, ALABAMA

APPLICATION OF FIRST PRINCIPLES Ni-Cd and Ni-H2 BATTERY MODELS TO SPACECRAFT OPERATIONS

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APPLICATION OF FIRST PRINCIPLES MODEL TO
SPACECRAFT OPERATIONS

OUTLINE

INTRODUCTION

REVIEW OF BI-PHASIC NICKEL ELECTRODE MODEL

EFFECTS OF AGING ON HYDROGEN PRESSURES

EFFECTS OF NICKEL ELECTRODE AGING

EFFECTS OF CADMIUM ELECTRODE AGING

SUMMARY

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INTRODUCTION

- PREVIOUS MODELS USE A SINGLE PHASE REACTION
- CYCLED CELL BEHAVIOR CANNOT BE PREDICTED WITH A SINGLE PHASE
- INTERPHASE CONVERSION PROVIDES MEANS FOR FILM AGING
- AGING CELLS PREDICTIONS DISPLAY TYPICAL BEHAVIORS
  - VOLTAGE FADING UPON CYCLING
  - SECOND PLATEAU ON DISCHARGE OF CYCLED CELLS
  - NEGATIVE LIMITED BEHAVIOR FOR Ni-Cd's
  - PRESSURE CHANGES IN NiH2 CELLS

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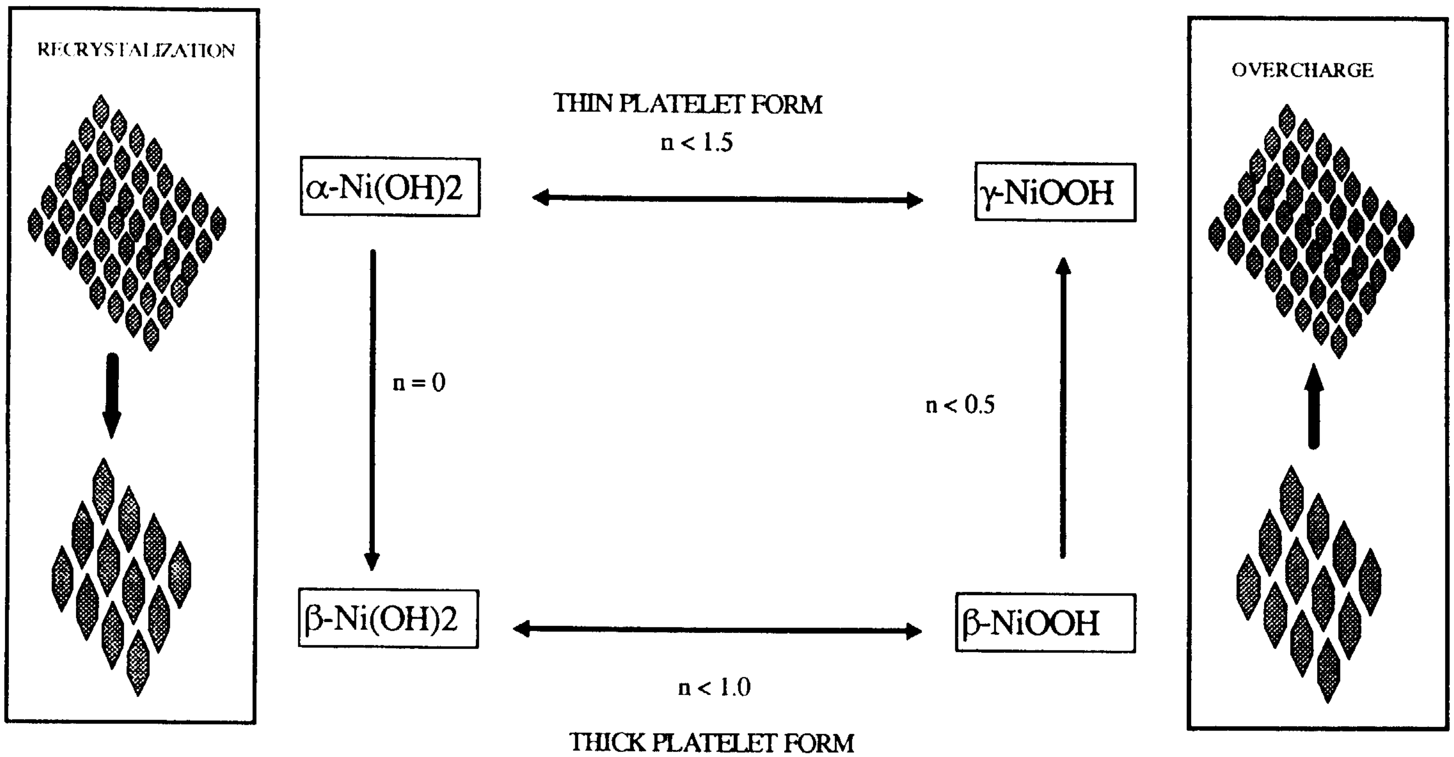
NICKEL ELECTRODE REACTION SCHEME



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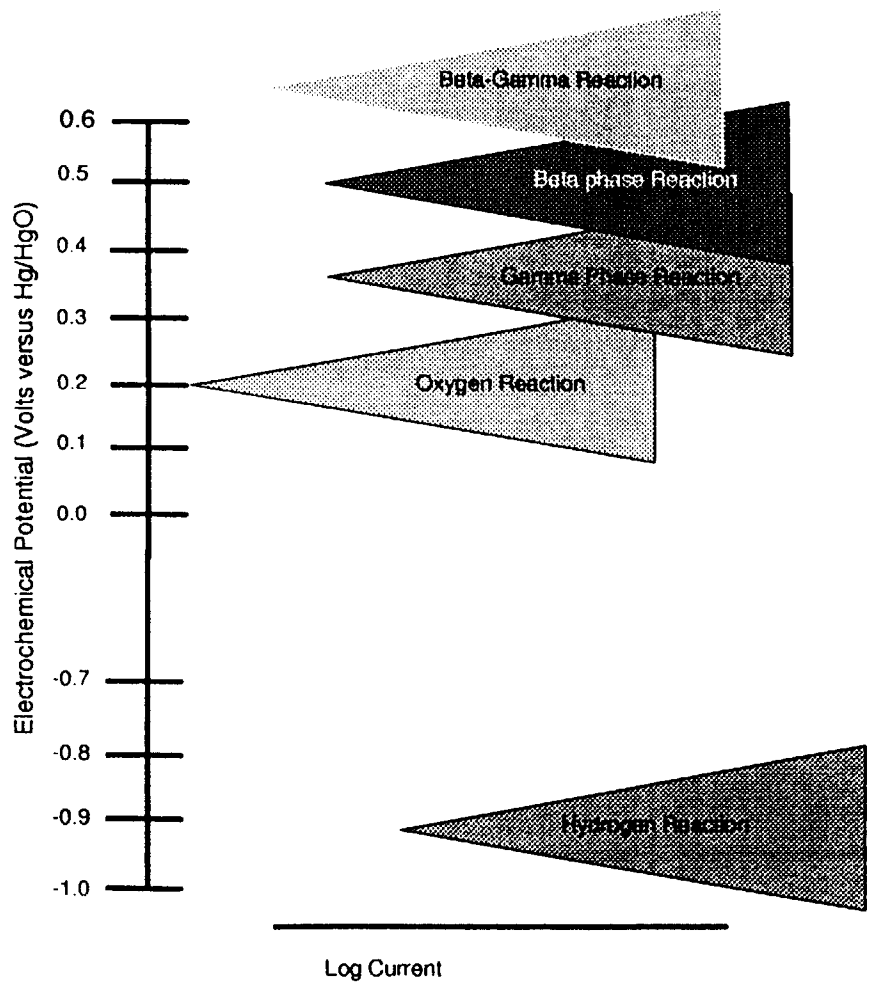
POTENITAL SCALE FOR NICKEL ELECTRODE MODEL



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NICKEL ELECTRODE FADING STUDIES

- BASED ON INTERPHASE CONVERSION
- AND CHANGES IN MORPHOLOGY / CONDUCTION
- TOPEX 40% DOD CRANE LIFE TEST DATA USED FOR COMPARISON
- ONLY POSITIVE ELECTRODE DEGRADED IN THIS SECTION
- SIMULATION OF VOLTAGE FADING OVER LIFE ACHIEVED
- SECOND PLATEAU BEHAVIOR INCREASES OVER LIFE

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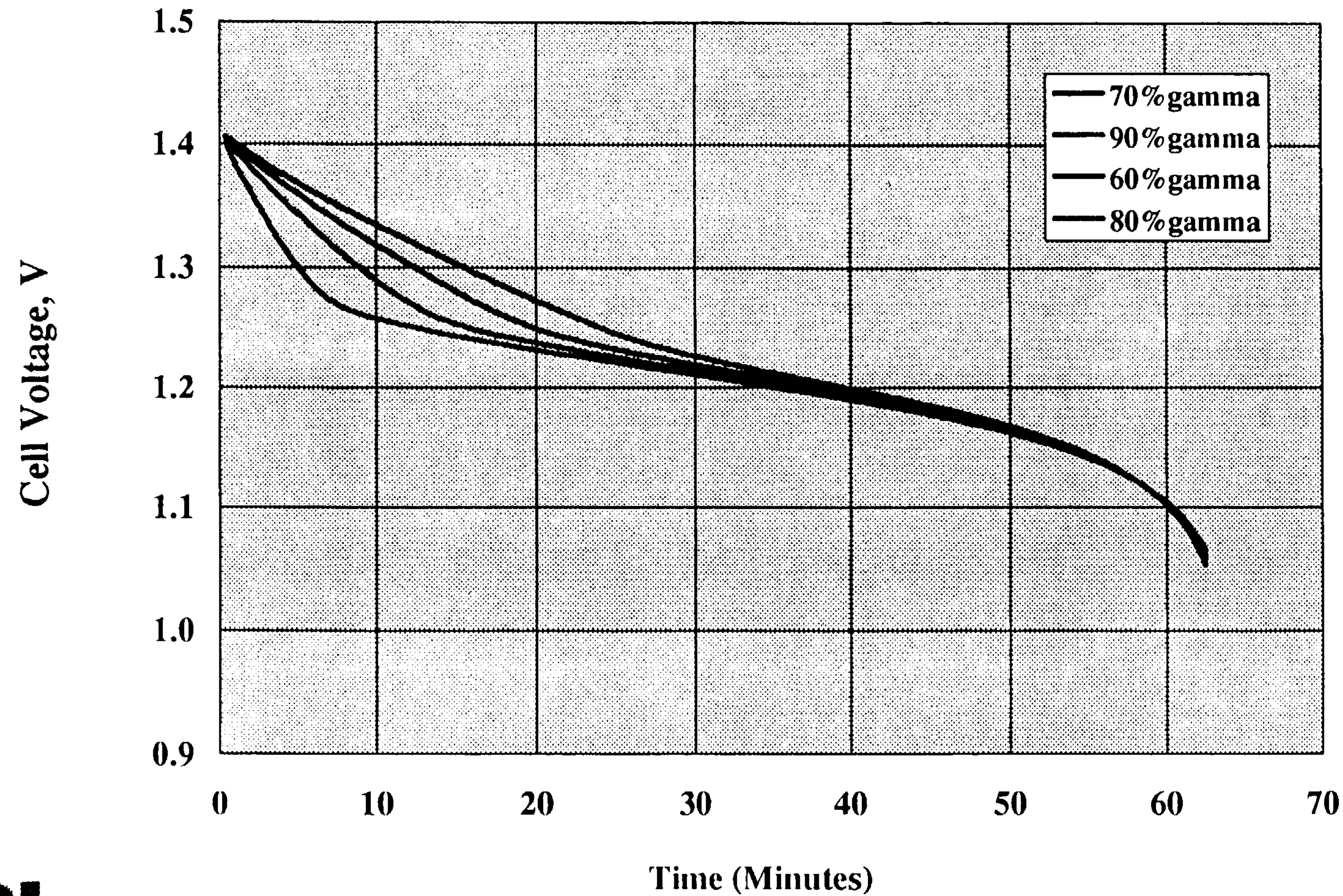
Effect of Gamma Fraction on Discharge Simulation



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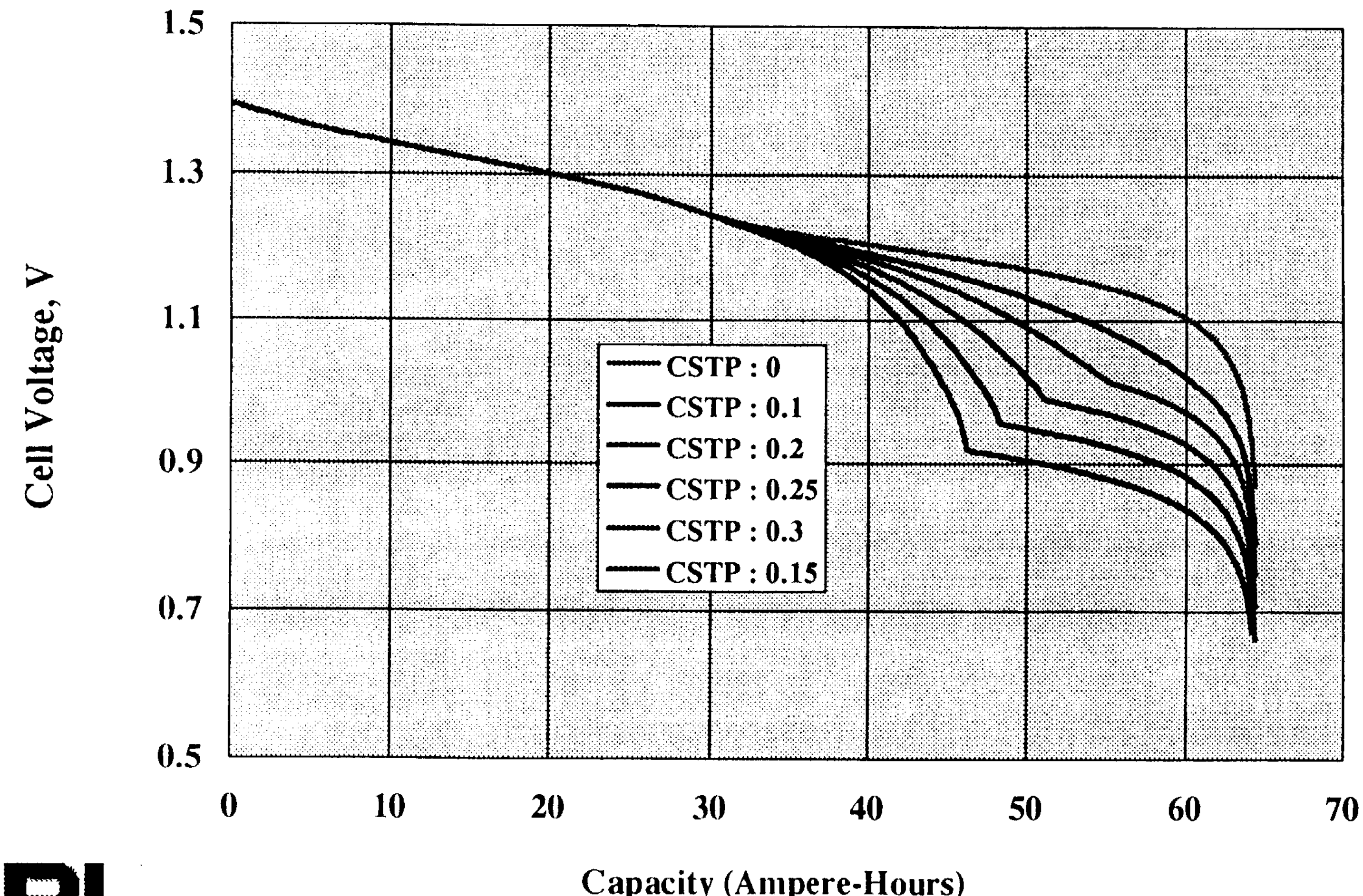
Effect of Conductivity Mixing Parameter (cstp)



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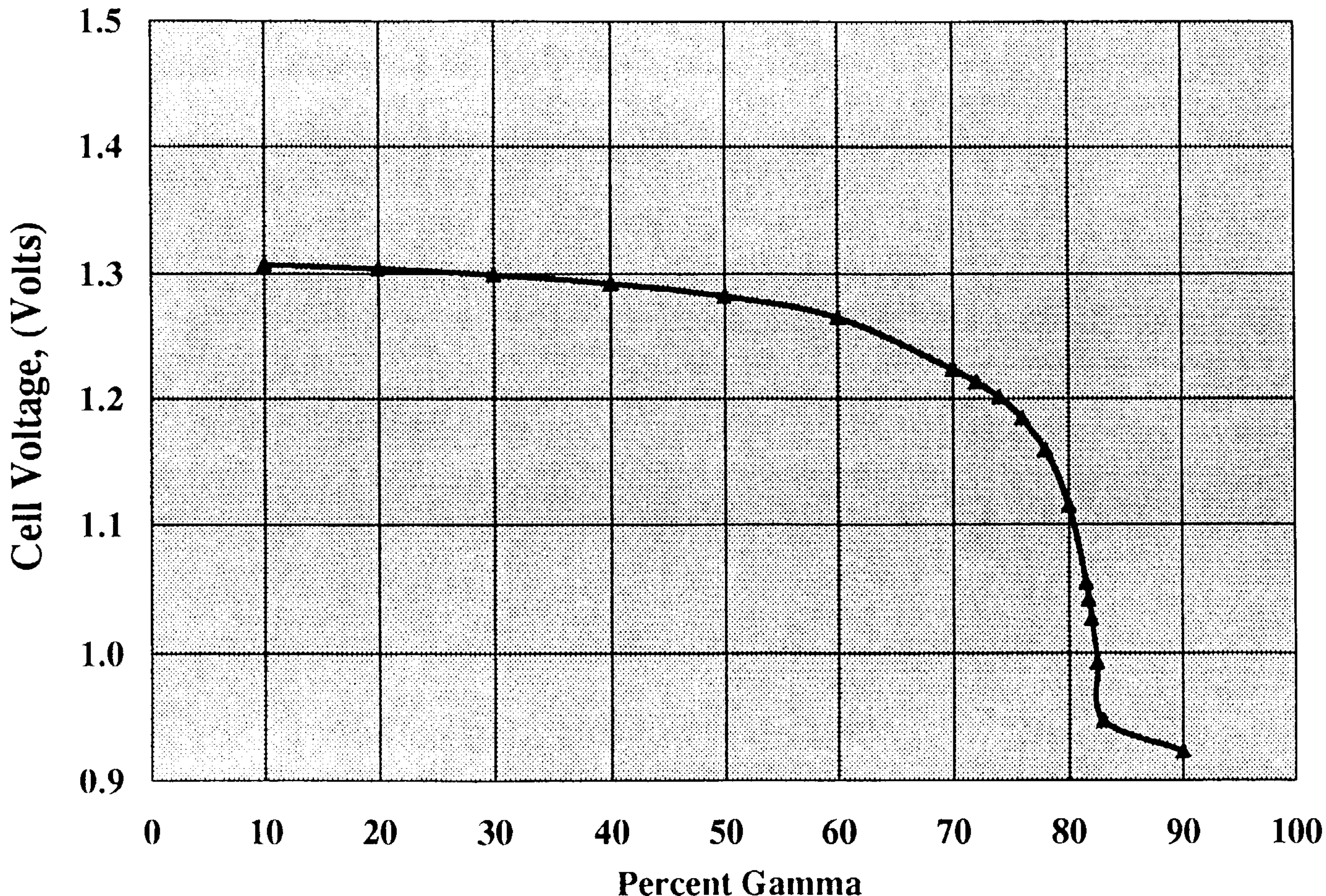
Effect of Gamma Fraction on 40% DOD LEO EON Voltage



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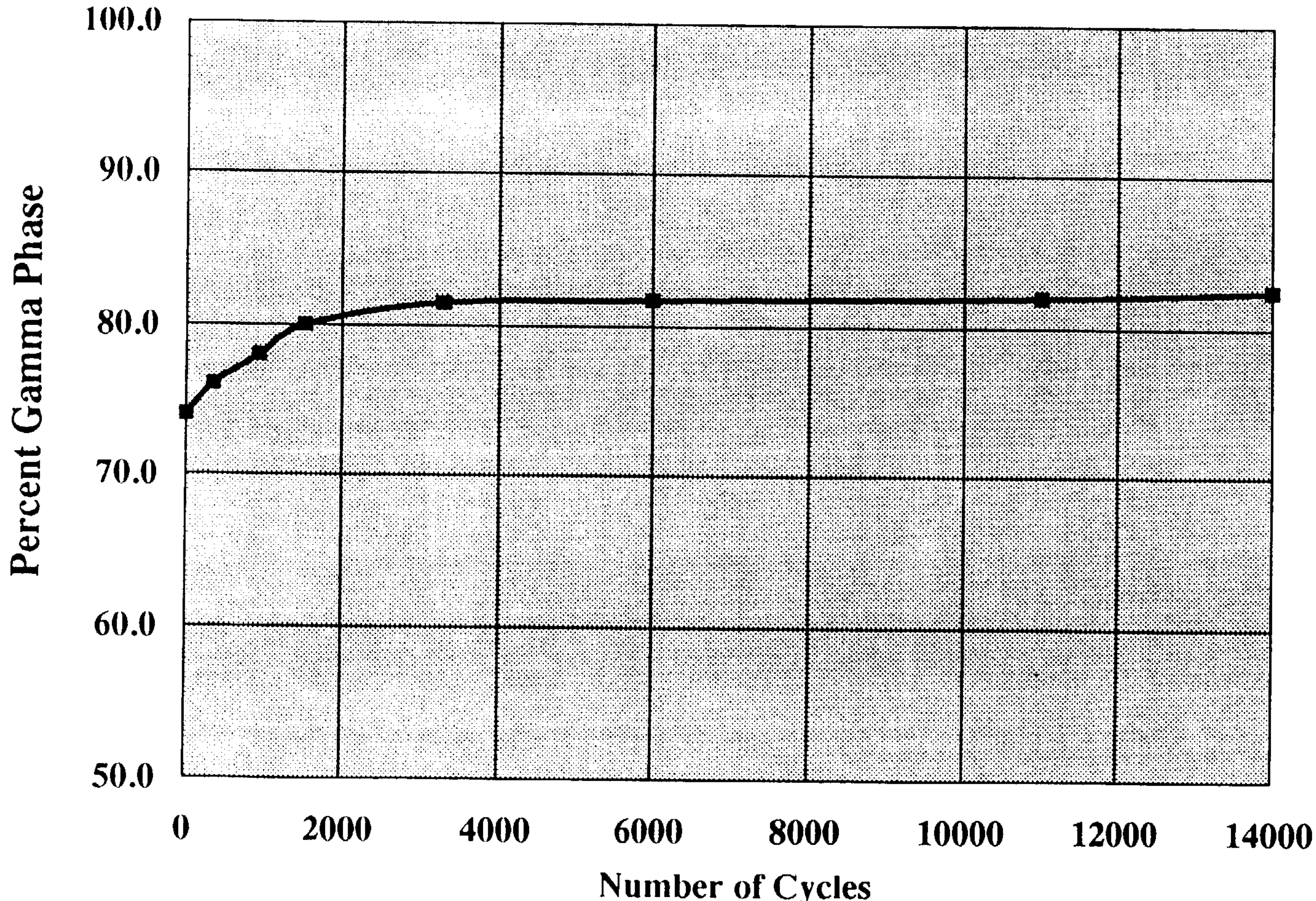
Estimated Gamma Fraction For Life Test



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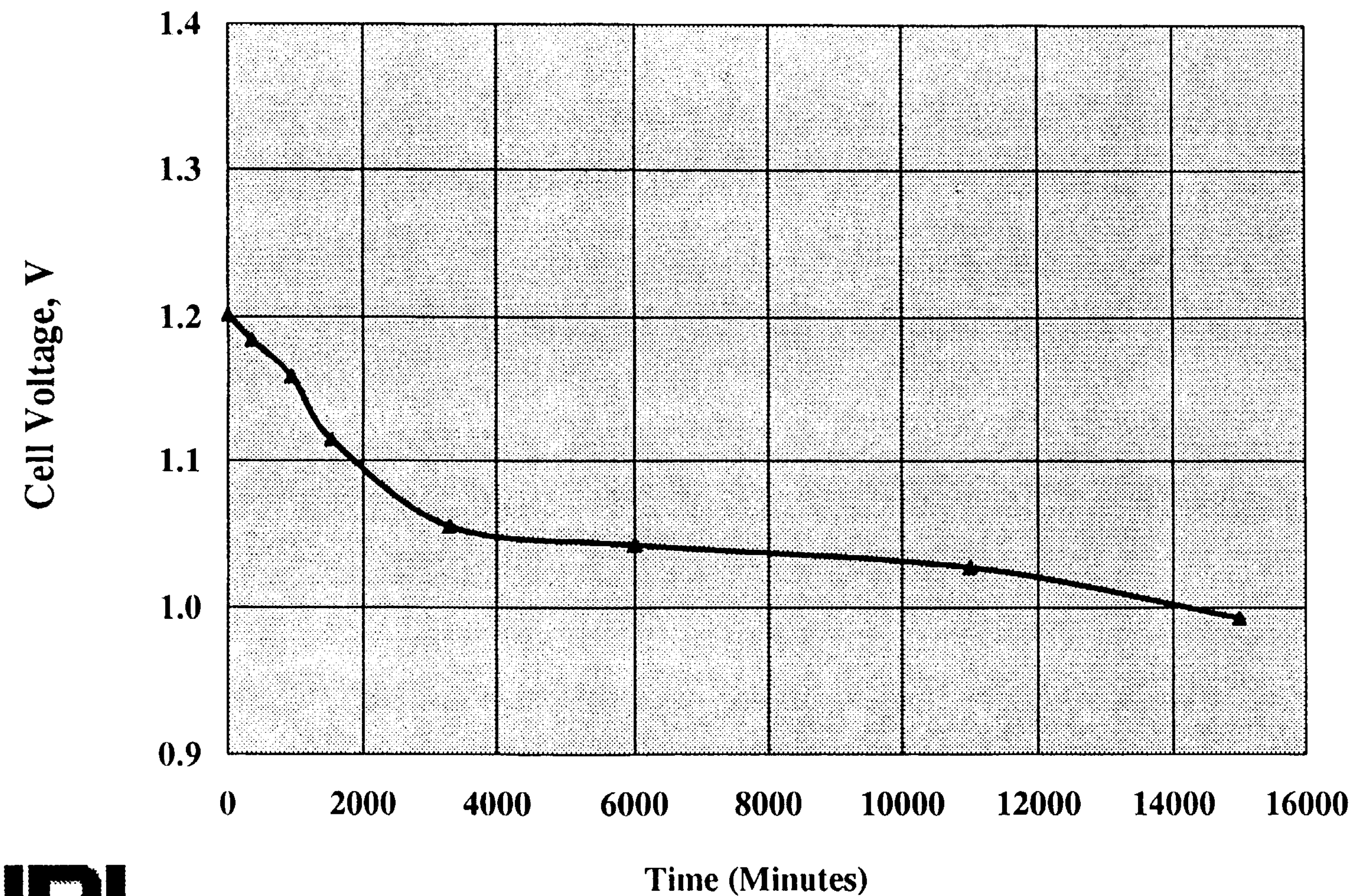
Predicted EON Voltages For Various Percent Gamma Phase



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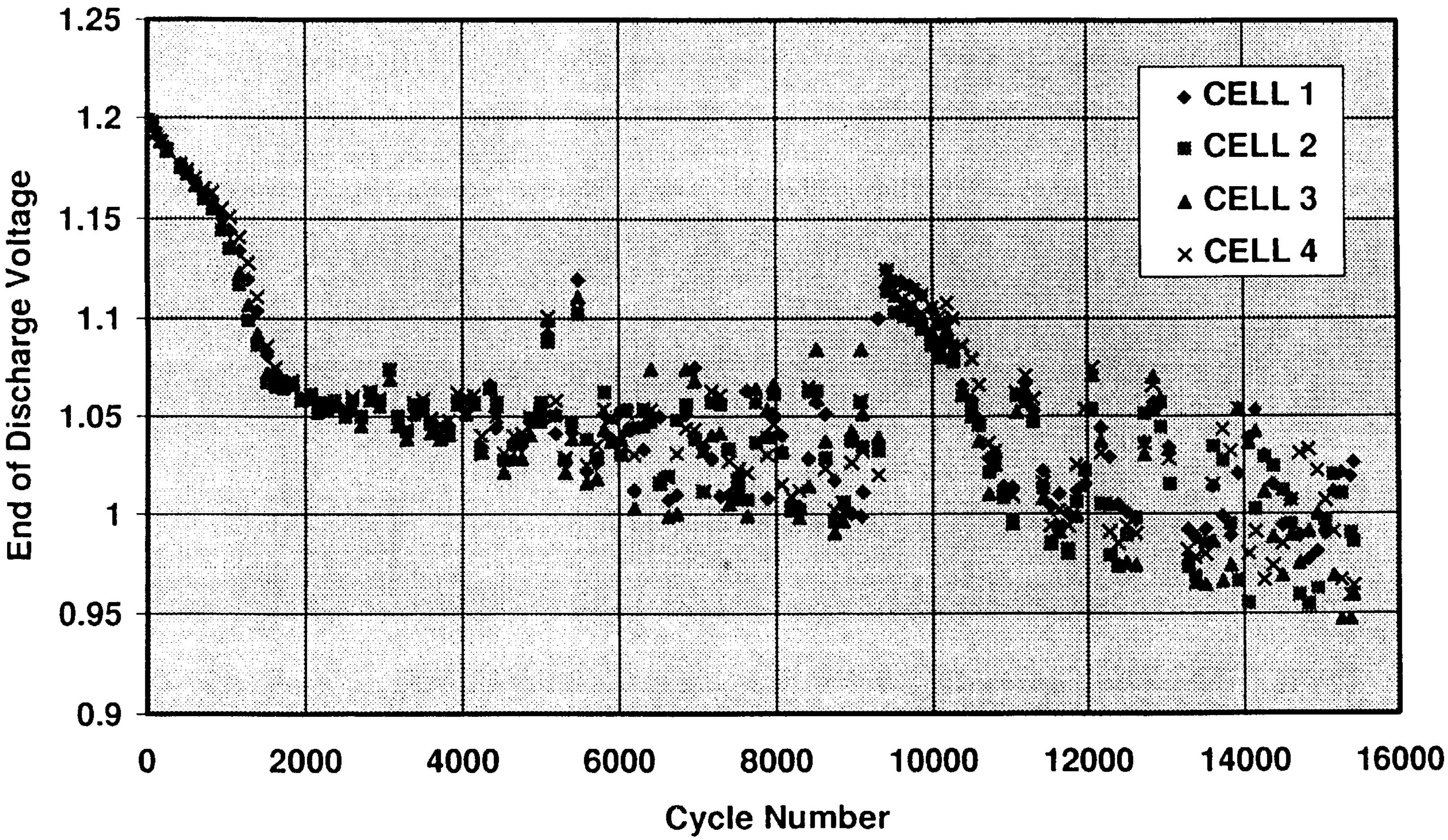
TOPEX NWSC Crane 40% DOD / 20°C Life Test



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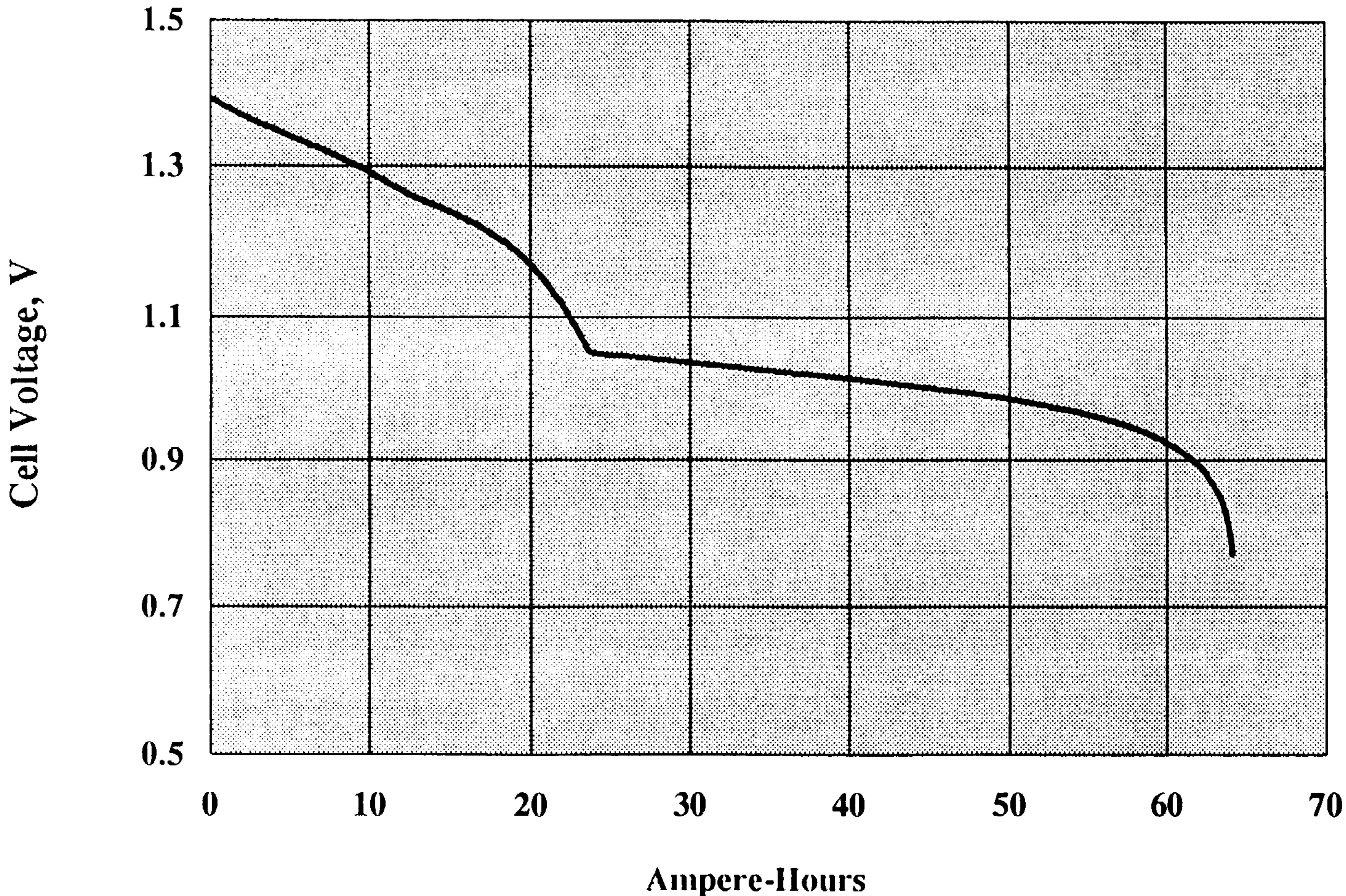
Predicted Discharge Voltage For Cycled Cell at C/2 Rate



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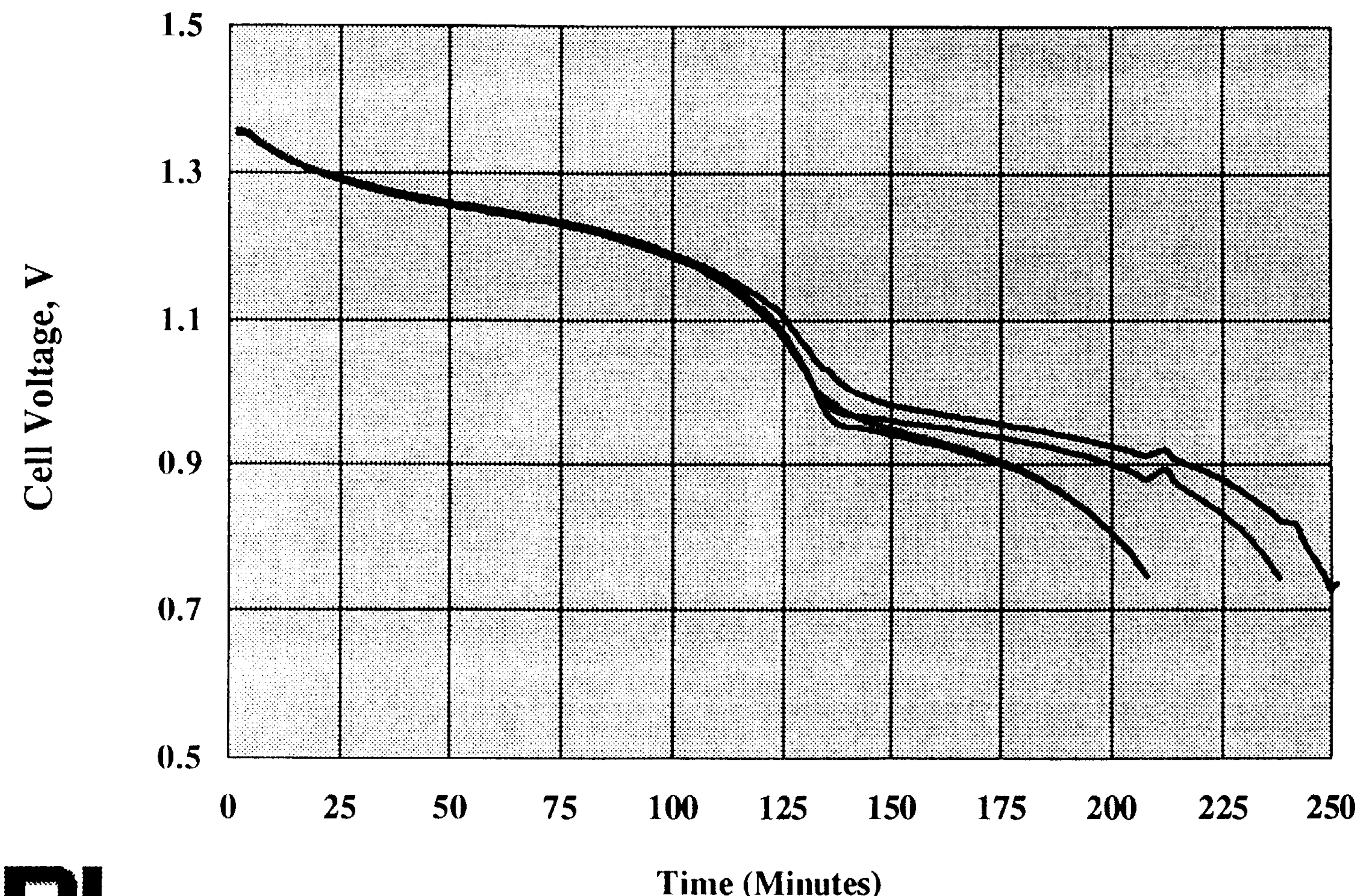
Post Life Test Discharge: Crane Topex Test



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STUDIES OF NEGATIVE LIMITED Ni-Cd CELLS

CAUSES

- INCREASED POSITIVE ELECTRODE CAPACITY
- CADMIUM ELECTRODE CAPACITY FADING
- CHANGES IN THE PRECHARGE LEVEL

EFFECTS

- HIGHER CELL POTENTIALS
- REDUCED CHARGE CURRENTS
- REDUCED CHARGE EFFICIENCY
- REDUCED STATE-OF-CHARGE
- DIVERGENCE OF SOC AND VOLTAGE IN BATTERY PACKS

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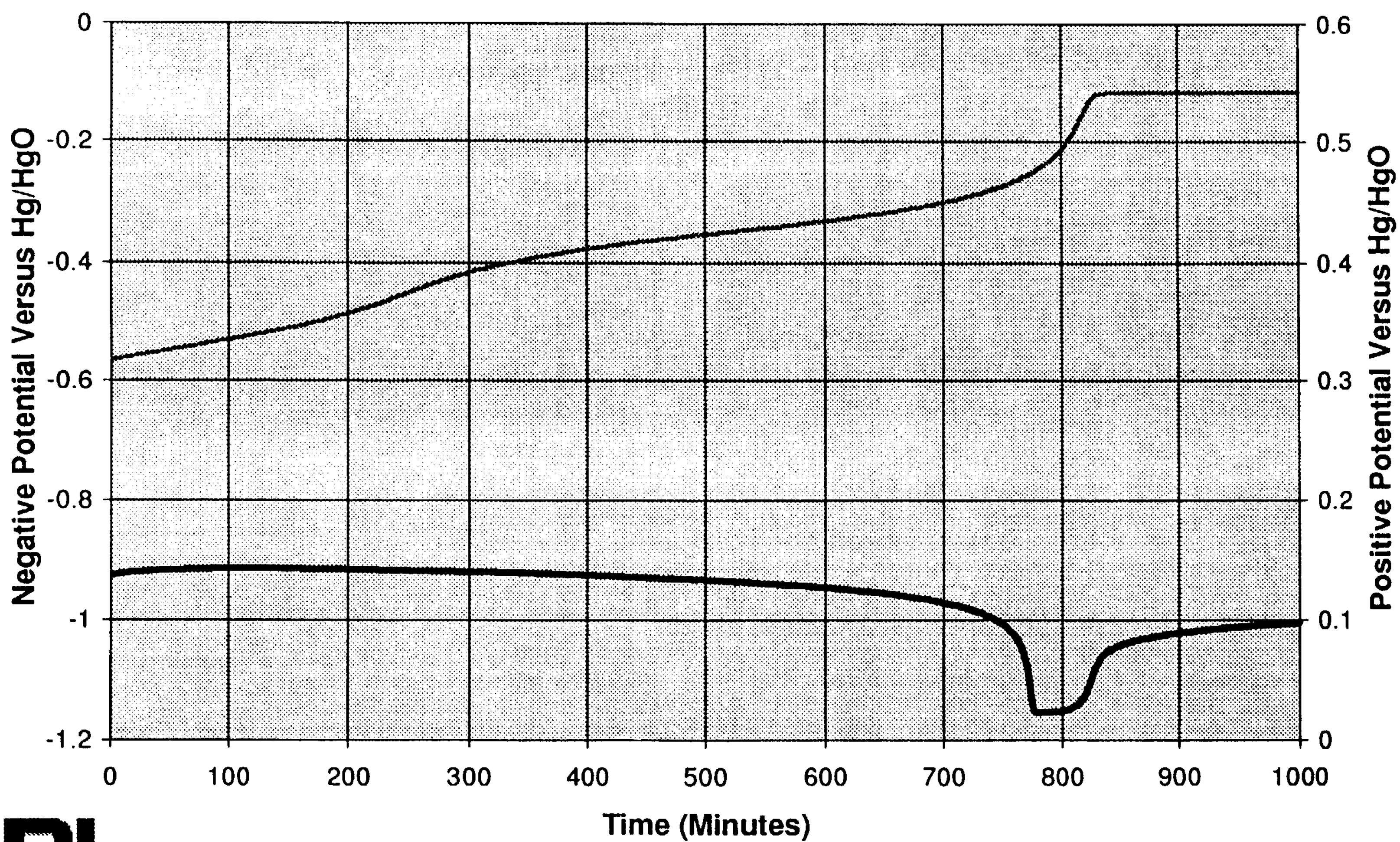
PREDICTED ELECTRODE POTENTIALS FOR NEGATIVE LIMITED CELL



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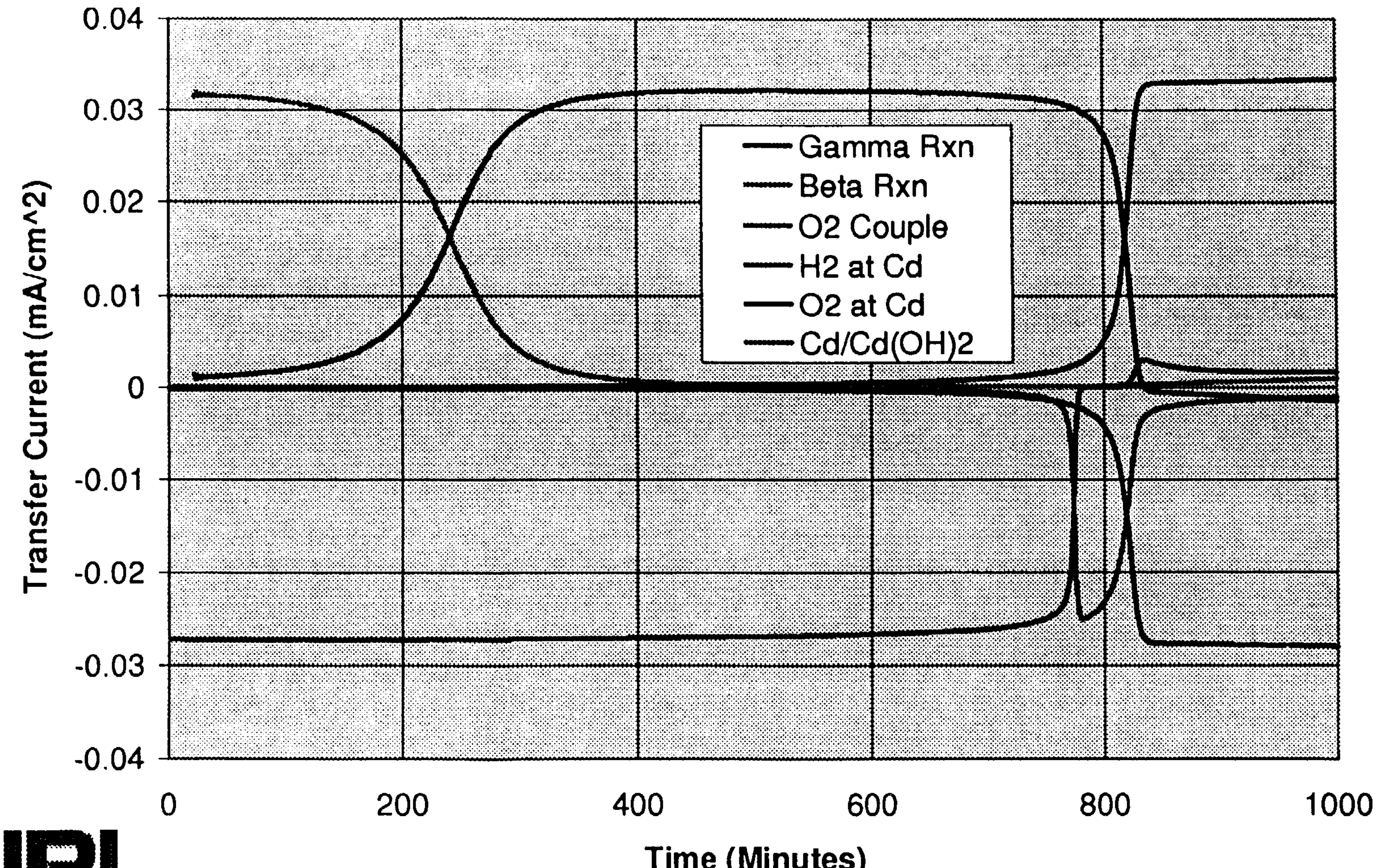
REACTION RATES FOR NEGATIVE LIMITED CELL ON CHARGE



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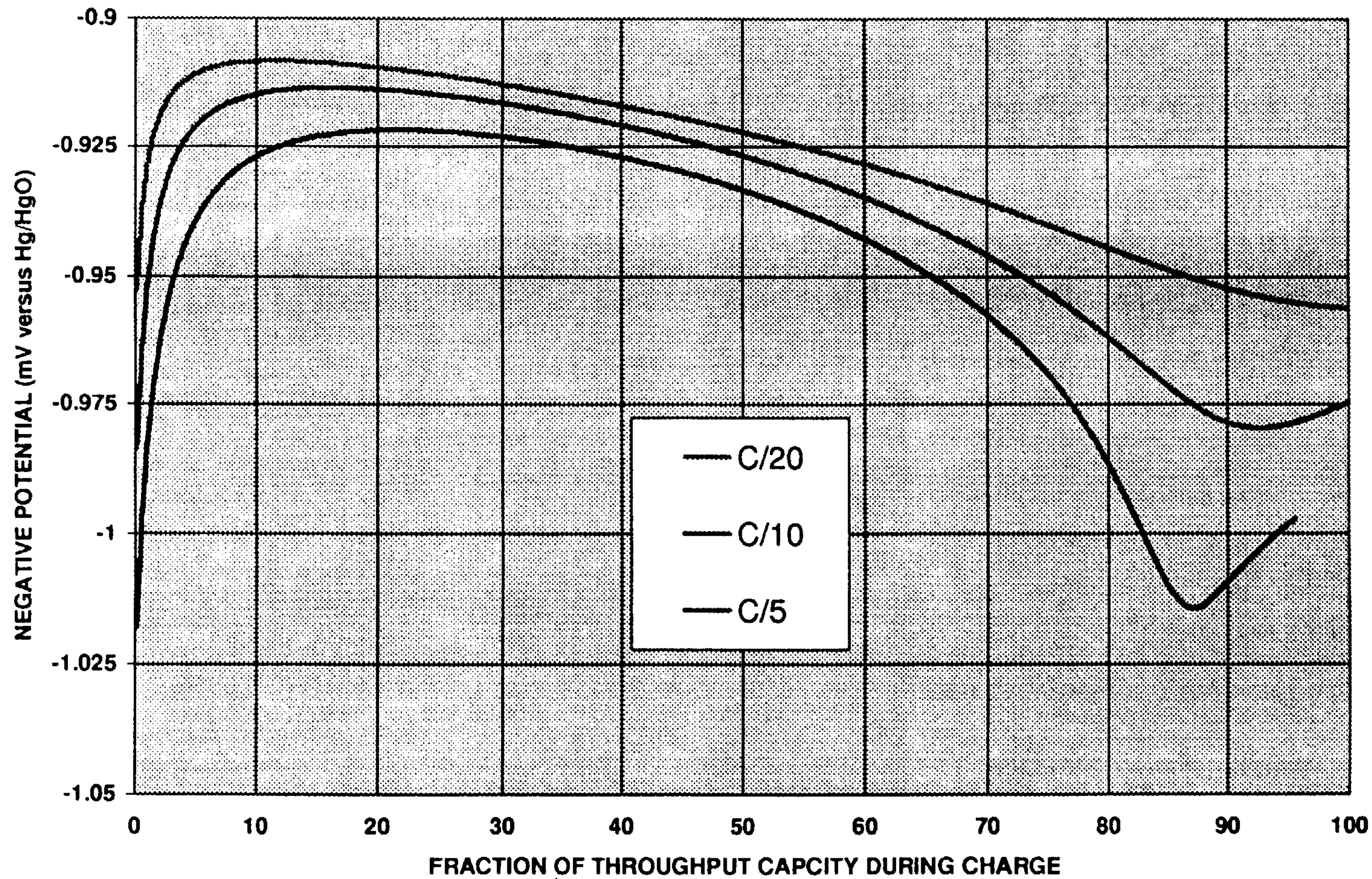
EFFECT OF CHARGE RATE ON NEGATIVE LIMITED CASE



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EFFECT OF NEGATIVE LIMITED LEO CYCLING

REGIME SELECTED TO SHOW THE EFFECT OF NEGATIVE LIMITED CELLS

SELECTED REGIME BASED ON RESULTS OF MPS TESTBED / TAGUCHI ANALYSIS

- HIGH CHARGE RATE
- HIGH VT LEVEL
- LOW DOD, 10 MINUTE DISCHARGE DURATION

THESE CONDITION ARE MOST LIKELY TO CAUSE NEGATIVE LIMITED BEHAVIOR

AMOUNT OF PRECHARGE IS VARIED AT THREE LEVELS

SOC's, POTENTIALS, CURRENTS, REACTION RATES WERE PREDICTED

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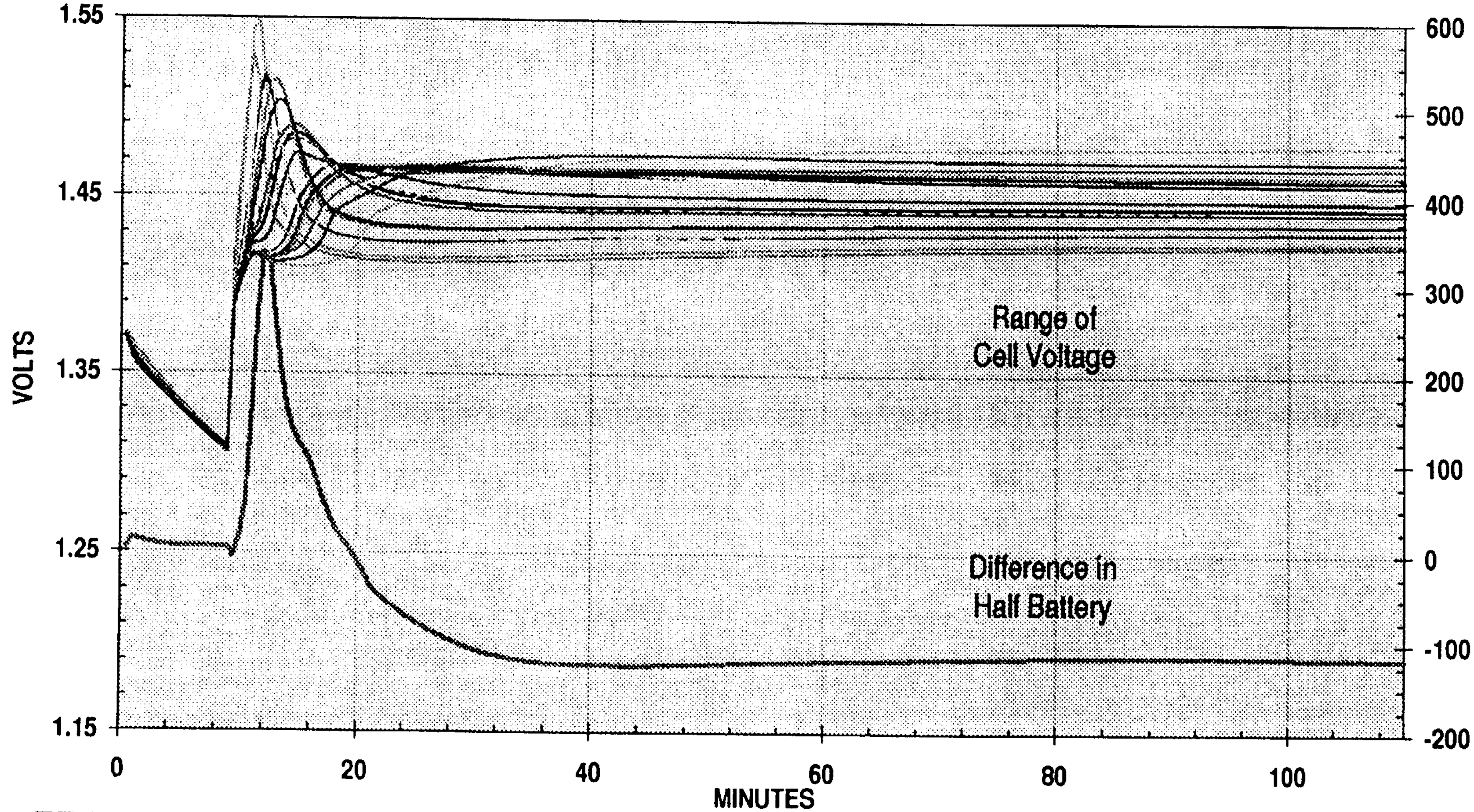
WORST CASE RESULT FROM TAGUCHI EXPERICMENT
5% DOD THEN 110 MINUTES @ 60A INRUSH TO 1.45 VPC AT 5° CELSIUS



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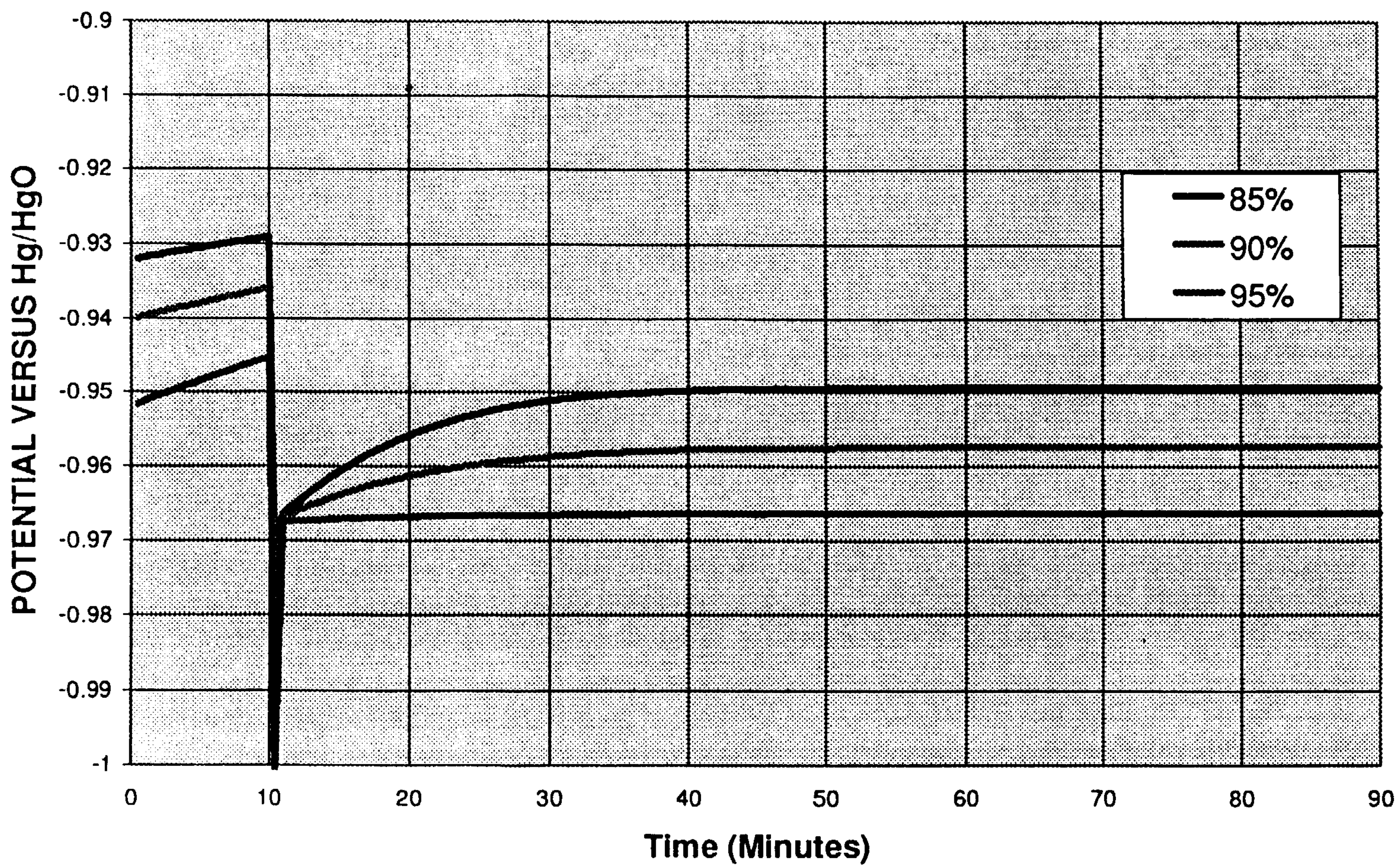
NEGATIVE ELECTRODE POTENTIALS FOR VARIOUS INTITIAL SOC's



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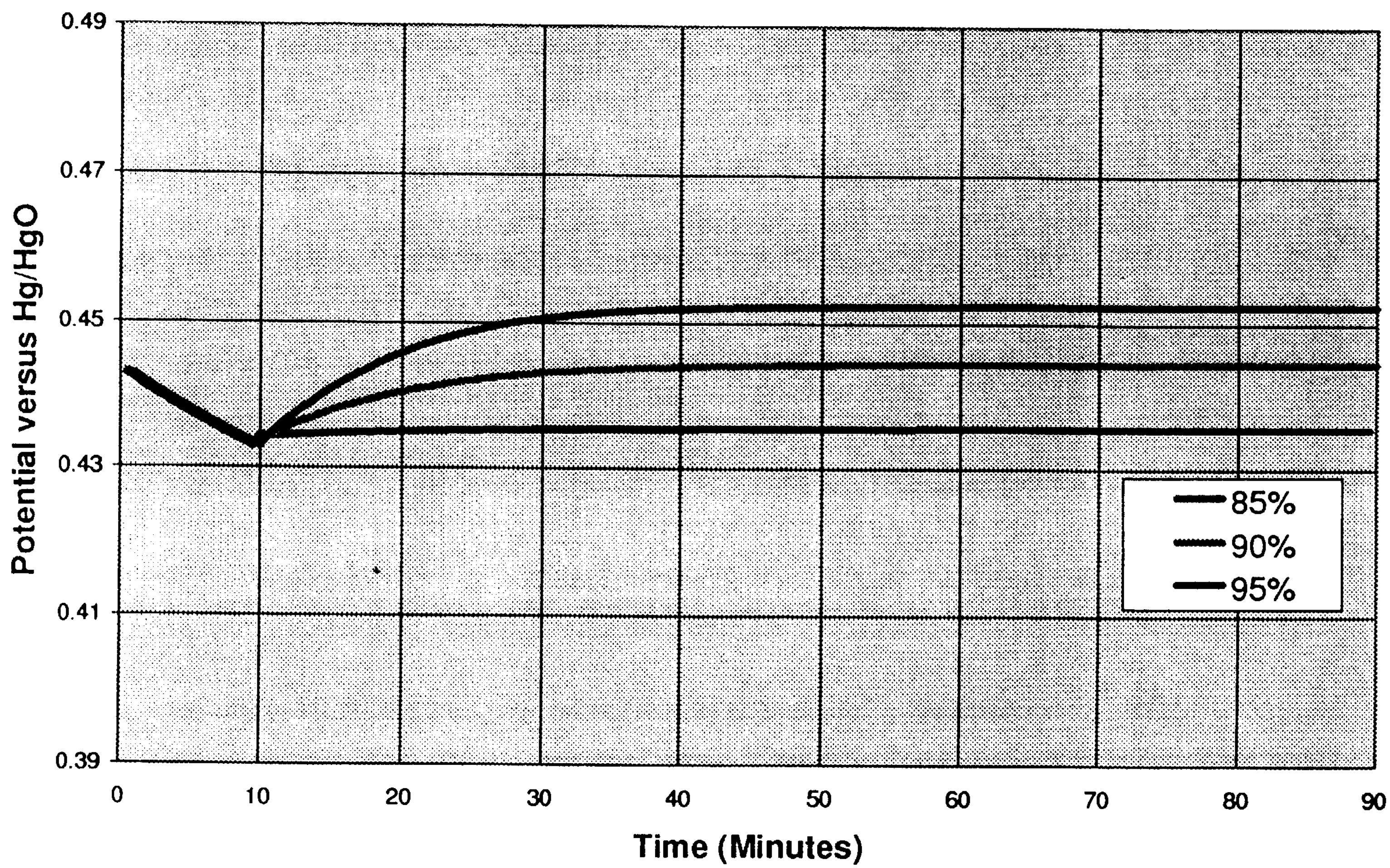
POSITIVE ELECTRODE POTENTIALS FOR VARIOUS INTITIAL Cd SOC's



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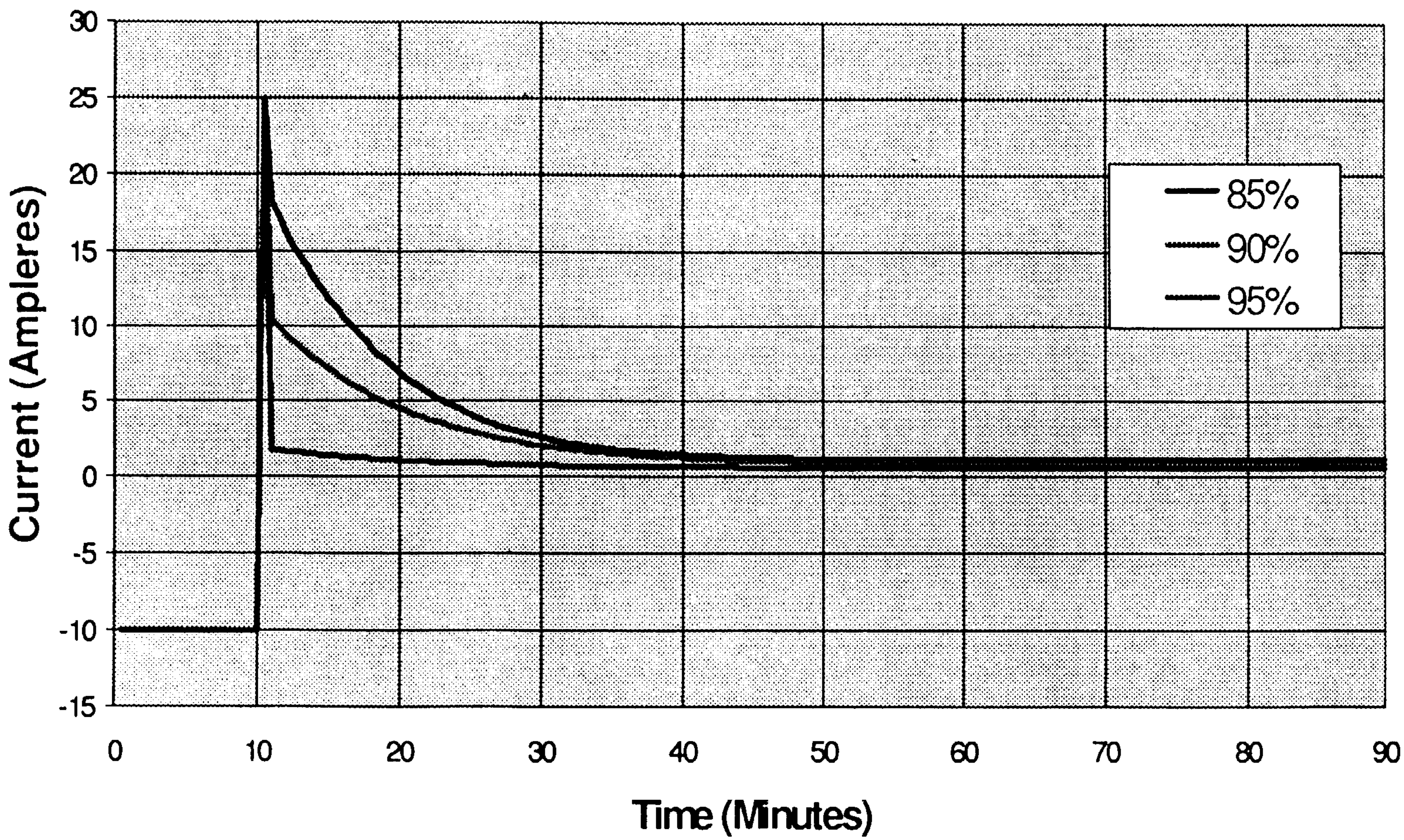
CURRENTS FOR VARIOUS INITIAL SOC's OF Cd ELECTRODE



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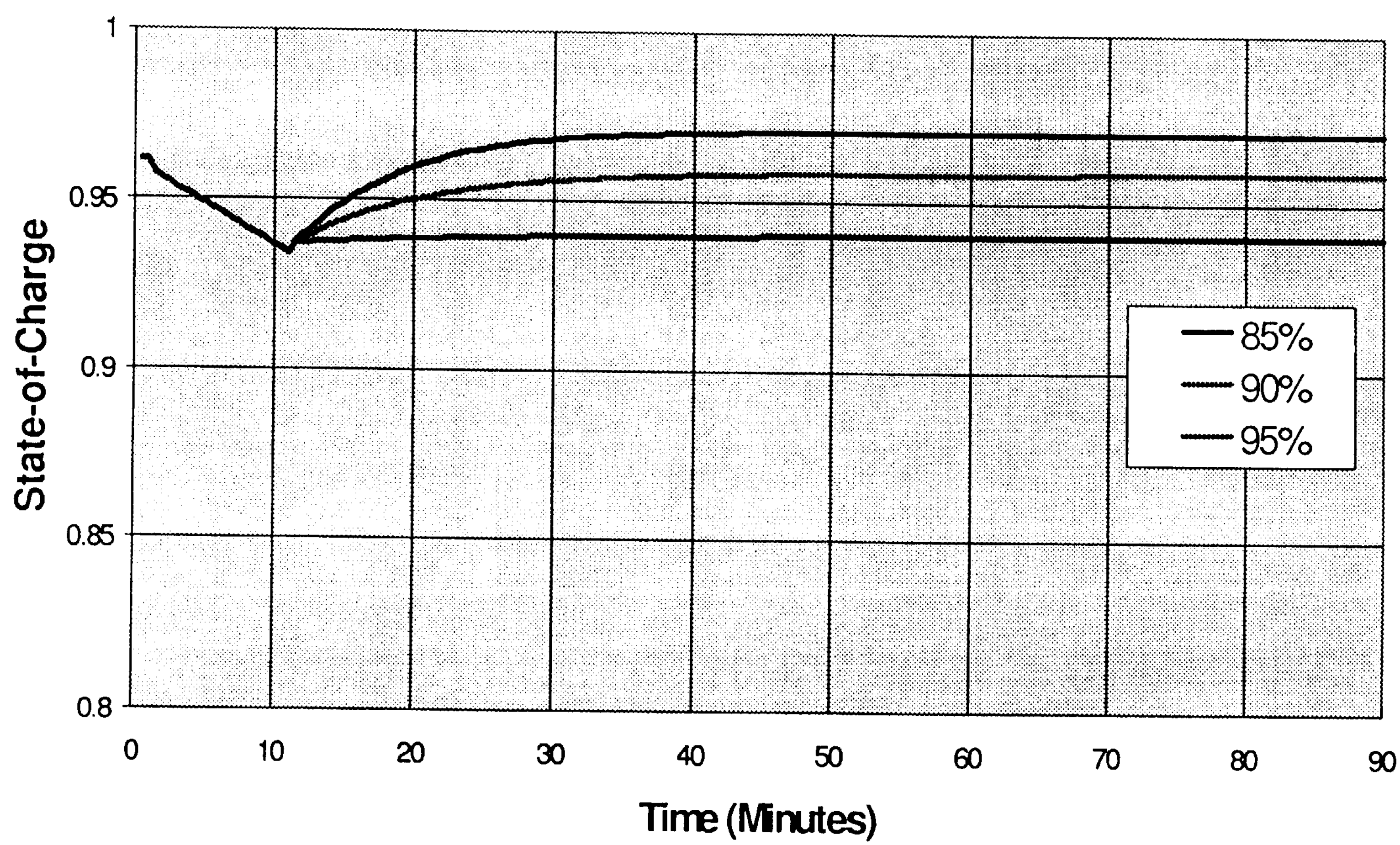
POSITIVE ELECTRODE SOC's FOR VARIOUS INITIAL Cd SOC's



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PRESSURE CHANGES IN Ni-H_2 CELLS

H_2 PRESSURE CHANGES EFFECT

- PRESSURE VESSEL SIZING
- PRECHARGE CHANGES

PRESSURE CHANGES DUE TO

- SINTER CORROSION - KNOWN
- PHASE CONVERSION - ADDITIONAL MECHANISM

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PRESSURE CHANGES DUE TO PHASE CHANGES

ASSUMING:	**CALCULATIONS:**
1 Liter Void Volume	53.6 AH = 2 Farads
50 AH Cell Design	For an increase of 0.5 e^-
1.0 e^-/ Ni Change at BOL	1 Equiv. H_2 is produced
Increased to 1.5 e^-/ Ni at EOL	Results in 160 psi increase
25 Degrees Celsius	

CONCLUSIONS

FIRST PRINCIPLES BI-PHASIC NICKEL ELECTRODE PRESENTED

MODEL PROVIDES AN EXPLANATION FOR MANY BEHAVIORS

- EON VOLTAGE FADING ON LEO CYCLING
- DEVELOPMENT OF SECOND PLATEAU ON CYCLING
- REDUCTION OF OVERCHARGE PROTECTION IN NiCd CELLS
  - ONSET OF NEGATIVE LIMITED BEHAVIOR
  - CELL DIVERGENCE ON LEO CYCLING
- VARIATION IN HYDROGEN PRECHARGE IN NiH2 CELLS

ACKNOWLEDGMENTS

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