1997 NASA BATTERY WORKSHOP

HUNTSVILLE, ALABAMA

APPLICATION OF FIRST PRINCIPLES MODEL TO SPACECRAFT OPERATIONS

Paul Timmerman, Ratnakumar Bugga, and Salvidor DiStefano

OUTLINE

INTRODUCTION

REVIEW **OF** BI-PHASIC NICKEL **ELECTRODE**

EFFECTS OF AGING ON **HYDROGEN" PRESSURES**

EFFECTS OF NICKEL **ELECTRODE AGING**

EFFECTS OF CADMIUM ELECTRODE AGING

SUMMARY

APPLICATION OF FIRST PRINCIPLES MODEL TO SPACECRAFT OPERATIONS

INTRODUCTION

PREVIOUS MODELS USE A SINGLE **PHASE REACTION**

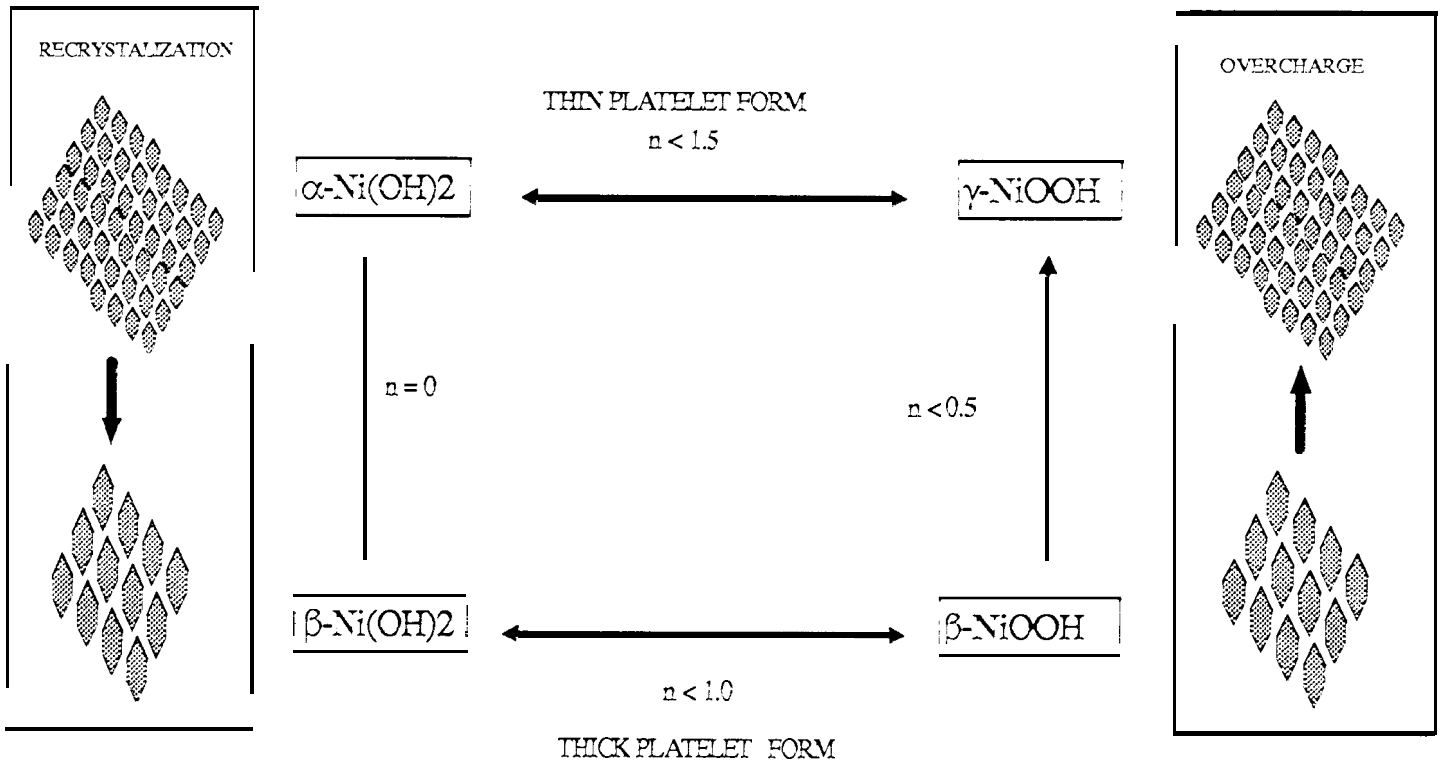
CYCLED CELL PREDICTS CANNOT **BE** MET WITH A **SINGLE PHASE**

INTERPHASE CONVERSION **PROVIDES** MEANS **FOR FILM** AGING

AGING **CELLS PREDICTIONS DISPLAY TYPICAL BEHAVIORS**

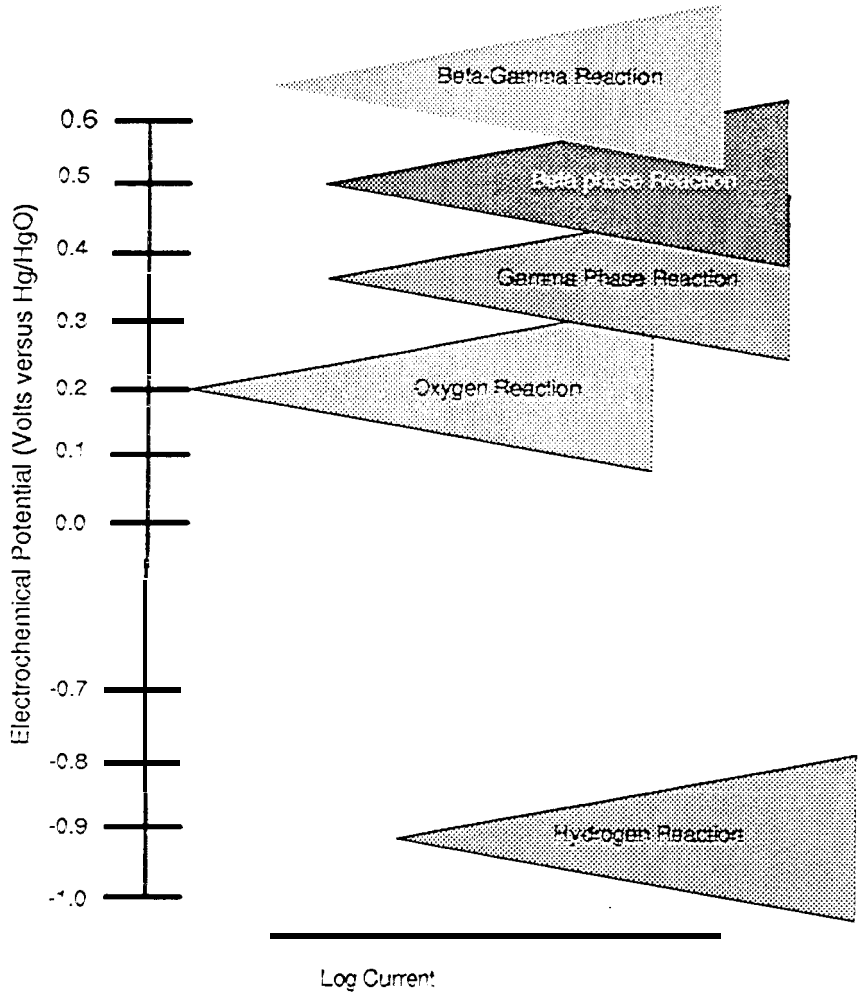
- **PRESSURE CHANGES N** NiH2 **CELLS**
- **VOLTAGE** FADING UPON **CYCLING**
- **SECOND PLATEAU** ON **DISCHARGE OF CYCLED CELLS**
- NEGATIVE **LIMITED BEHAVIOR FOR** Ni-Cd's

NICKEL ELECTRODE REACTION SCHEME



APPLICATION OF FIRST PRINCIPLES MODEL TO SPACECRAFT OPERATIONS

POTENITAL SCALE FOR NICKEL ELECTRODE MODEL



PRESSURE CHANGES IN $Ni-H_2$ CELLS

PRESSURE INCREASE ON CYCLING ATTRIBUTED TO NICKEL SINTER **CORROSION**

CHANGES IN PRECHARGE DURING **STORAGE HAVE** BEEN UNEXPLAINED

CONTROL **OF** PRECHARGE IS **IMPORTANT TO** REDUCING **CAPACITY LOSES**

DIFFERENT AMOUNTS OF **HYDROGEN ARE STORED WITH THE VARIOUS PHASES**

CYCLNG CAUSES AN **INCREASED** GAMMA **PHASE** - HIGHER OXIDATION **STATES**

HIGHER Ni **OXIDATION STATE-S CAUSE** $Ni(OH)_2$ **TO GIVE** UP H_2 **NTO CELL**

THEREFORE ACCLWULATIOX OF GAMMA MUST **NCREASE** H_2 PRESSURE

LIKEWISE OVERCHARGE OR STAND CAN CHANGE H_2 **PRECHARGE**

PRESSURE CHANGES DUE TO PHASE CHANGES

ASSUMING:

1 Liter Void Volume

50 AH Cell

1.0 e-/ Ni Change at BOL

Increase 0.5 e-/ Ni at EOL

25 Degrees Celsius

CALCULATIONS:

53.6 AH= 2 Farads

For a Change of OS e^-

1 Equiv. H^+ is produced

= 0.5 Equiv H_2 ,

= 11 Atm., 160 psi

STUDIES OF NEGATIVE LIMITED Ni-Cd CELLS

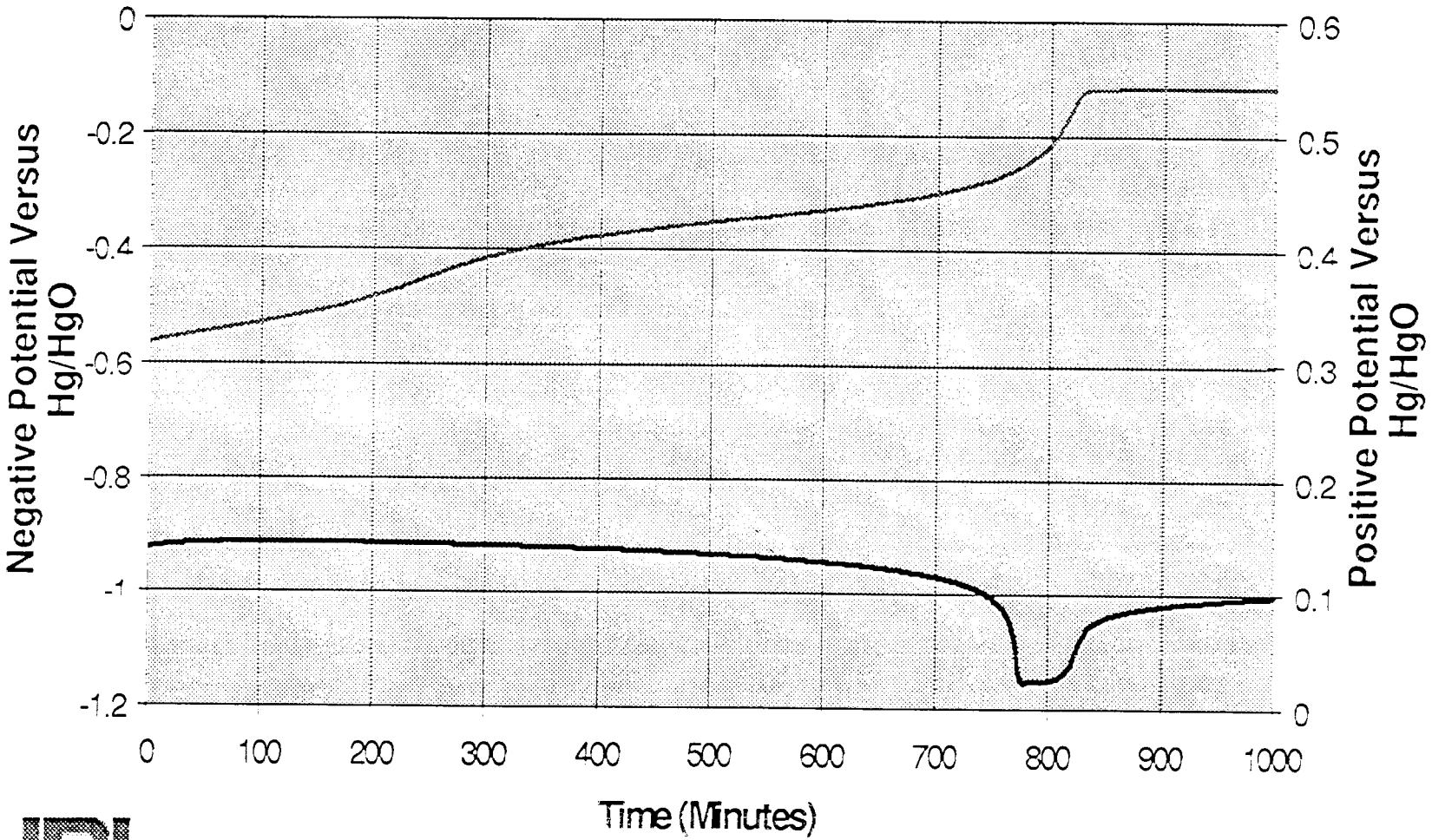
CAUSES

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

EFFECTS

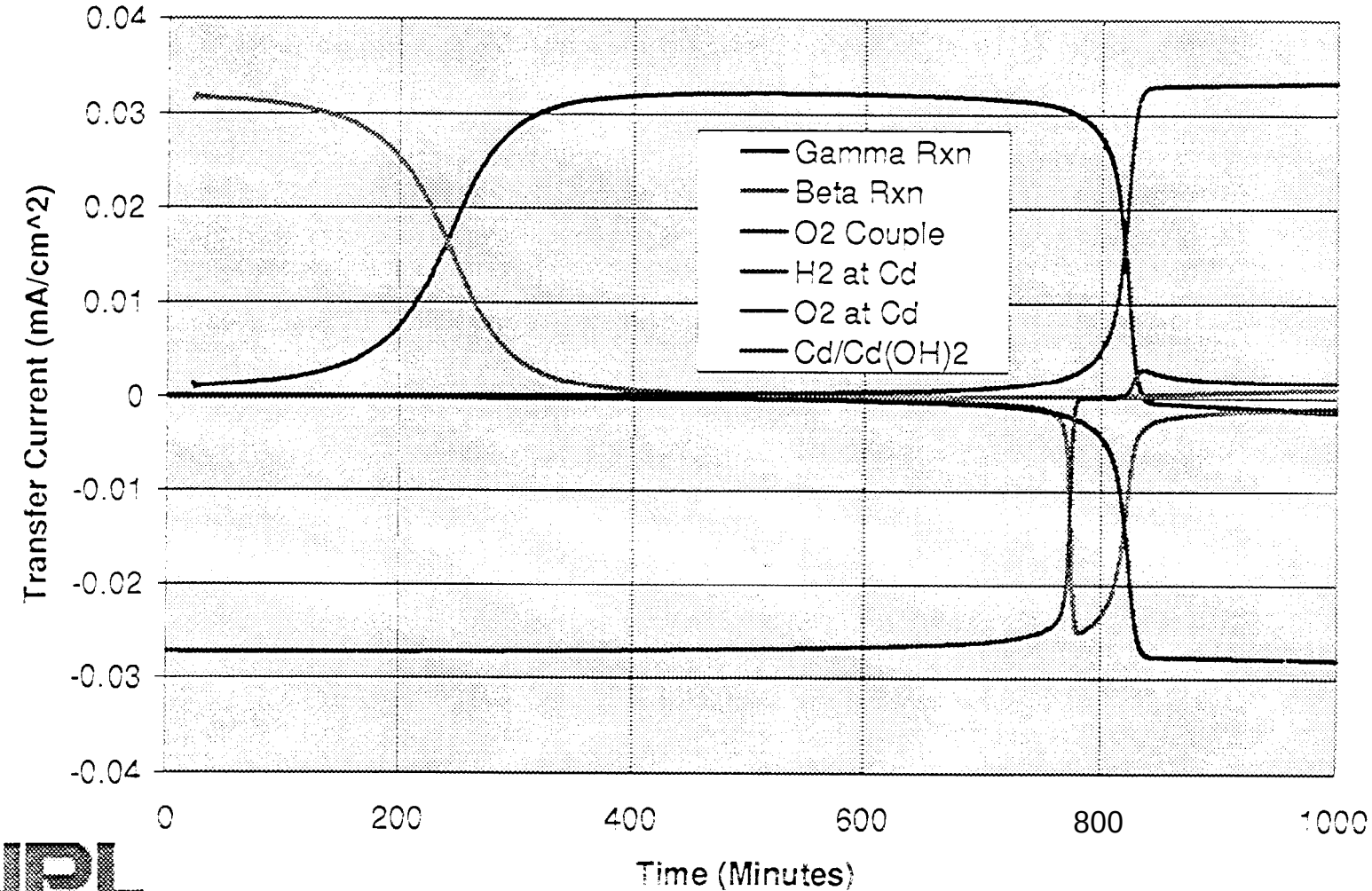
- **HIGHER CELL POTENTIALS**
- **REDUCED CHARGE** CURRENTS
- REDUCED **CHARGE** EFFICIENCY
- REDUCED **STATE-OF-CHARGE**
- **DIVERGENCE OF SOC** AND **VOLTAGE** IN BATTERY **PACKS**

ELECTRODE POTENTIALS FOR NEGATIVE LIMITED CELL



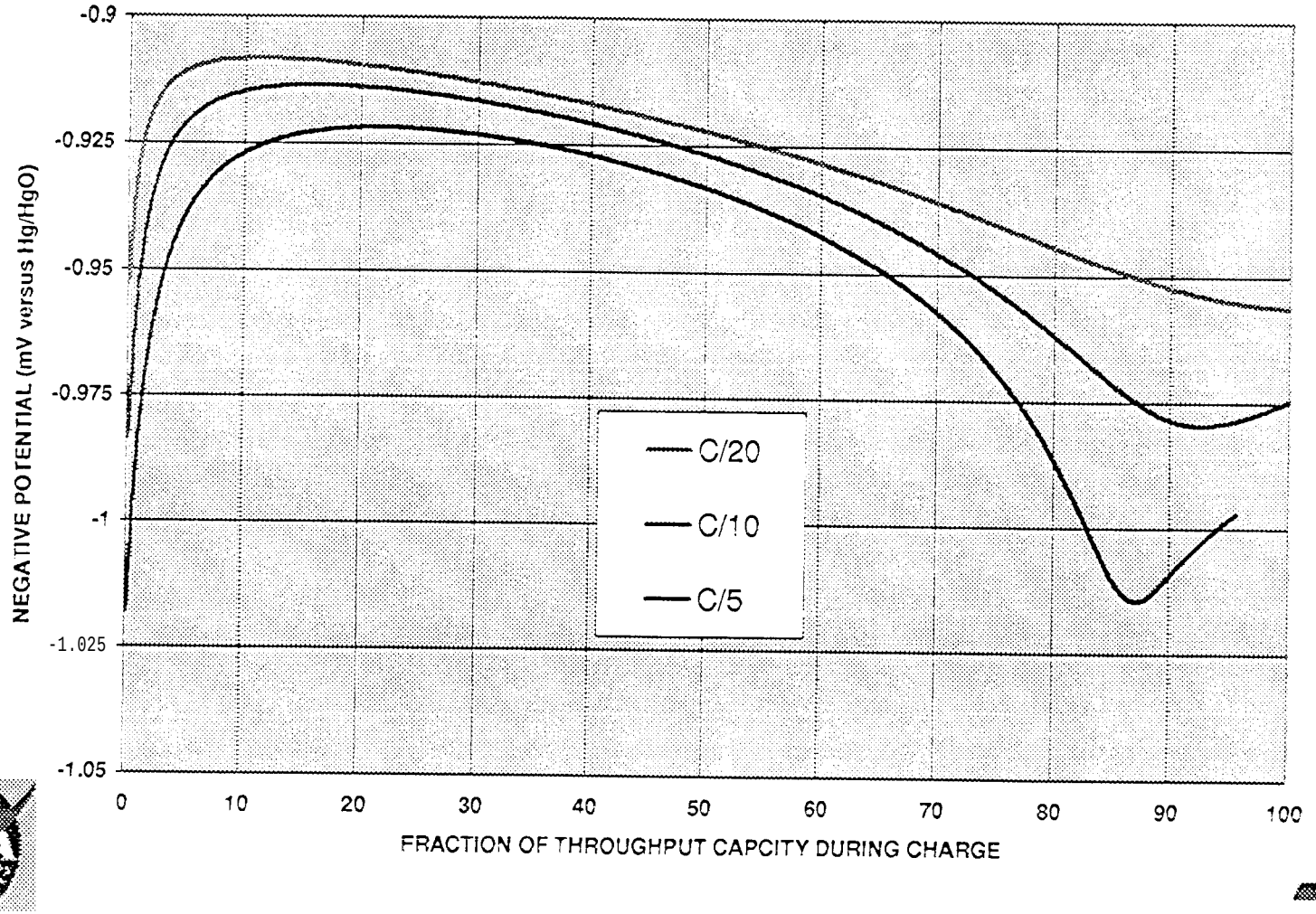
APPLICATION OF FIRST PRINCIPLES MODEL TO SPACECRAFT' OPERATIONS

REACTION RATES FOR NEGATIVE LIMITED CELL ON CHARGE



APPLICATION' OF FIRST PRINCIPLES MODEL TO SPACECRAFT' OPERATIONS

EFFECT OF CHARGE RATE ON NEGATIVE LIMITED CASE



APPIJCATION OF FIRST PRINCIPLES MODEL TO SPACECRAFT OPERATIONS

EFFECT OF NEGATIVE LIMITED LEO CYCLING

REGIME SELECTED TO SHOW THE EFFECT OF NEGATIVE LIMITED CELLS

SELECTED BASED ON RESULTS OF MPS TESTBED / TAGUCHI ANALYSIS

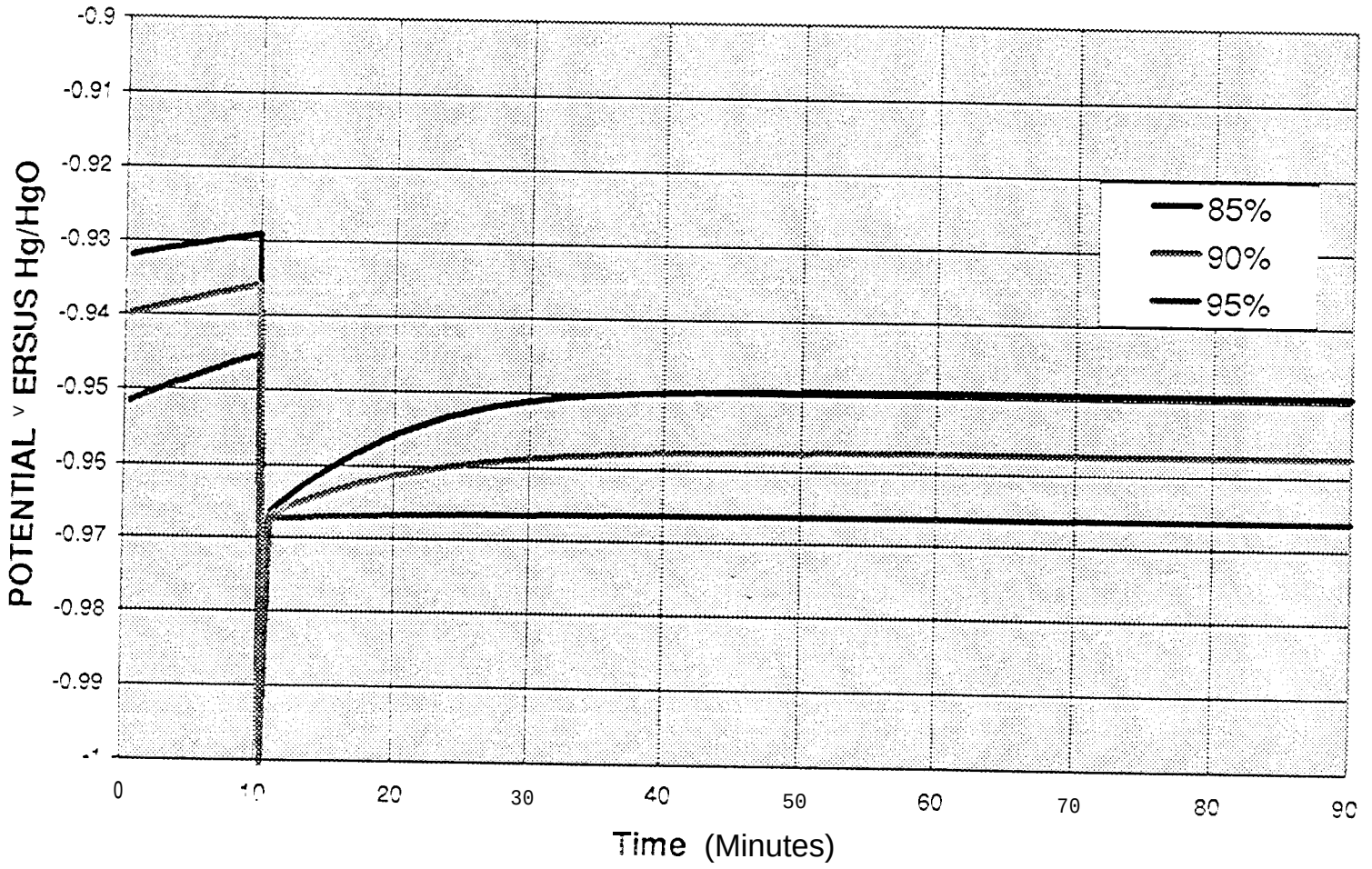
- **HIGH CHARGE RATE**
- HIGH VT LEVEL
- **90 MINUTE OBIT**
- **LOW DOD, 10 MINUTE DISCHARGE DURATION**

AMOUNT OF PRECHARGE IS VARIED AT THREE LEVELS

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

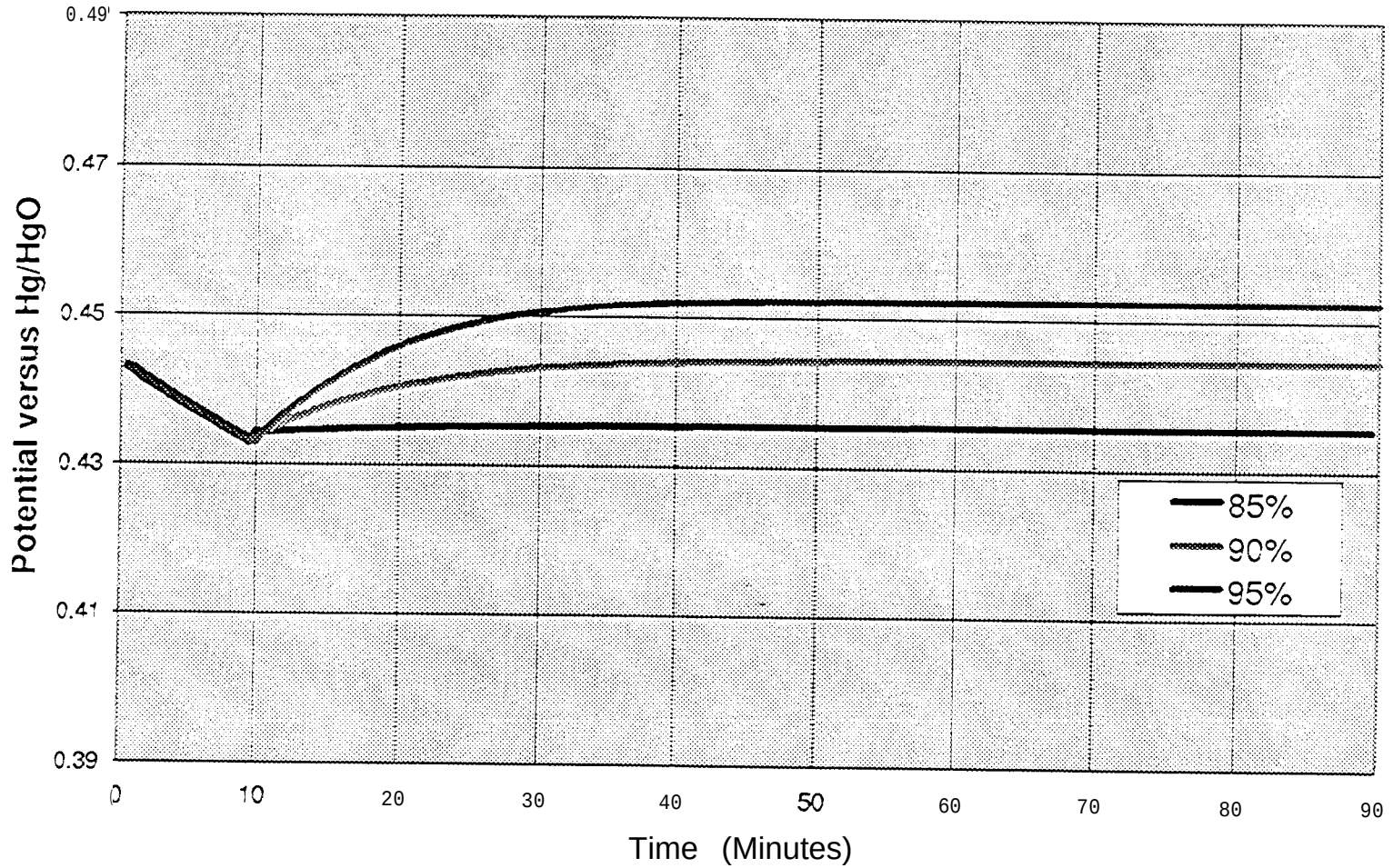
APPLICATION OF FIRST PRINCIPLES MODEL TO SPACECRAFT OPERATIONS

NEGATIVE ELECTRODE POTENTIALS FOR VARIOUS INTITIAL SOC's



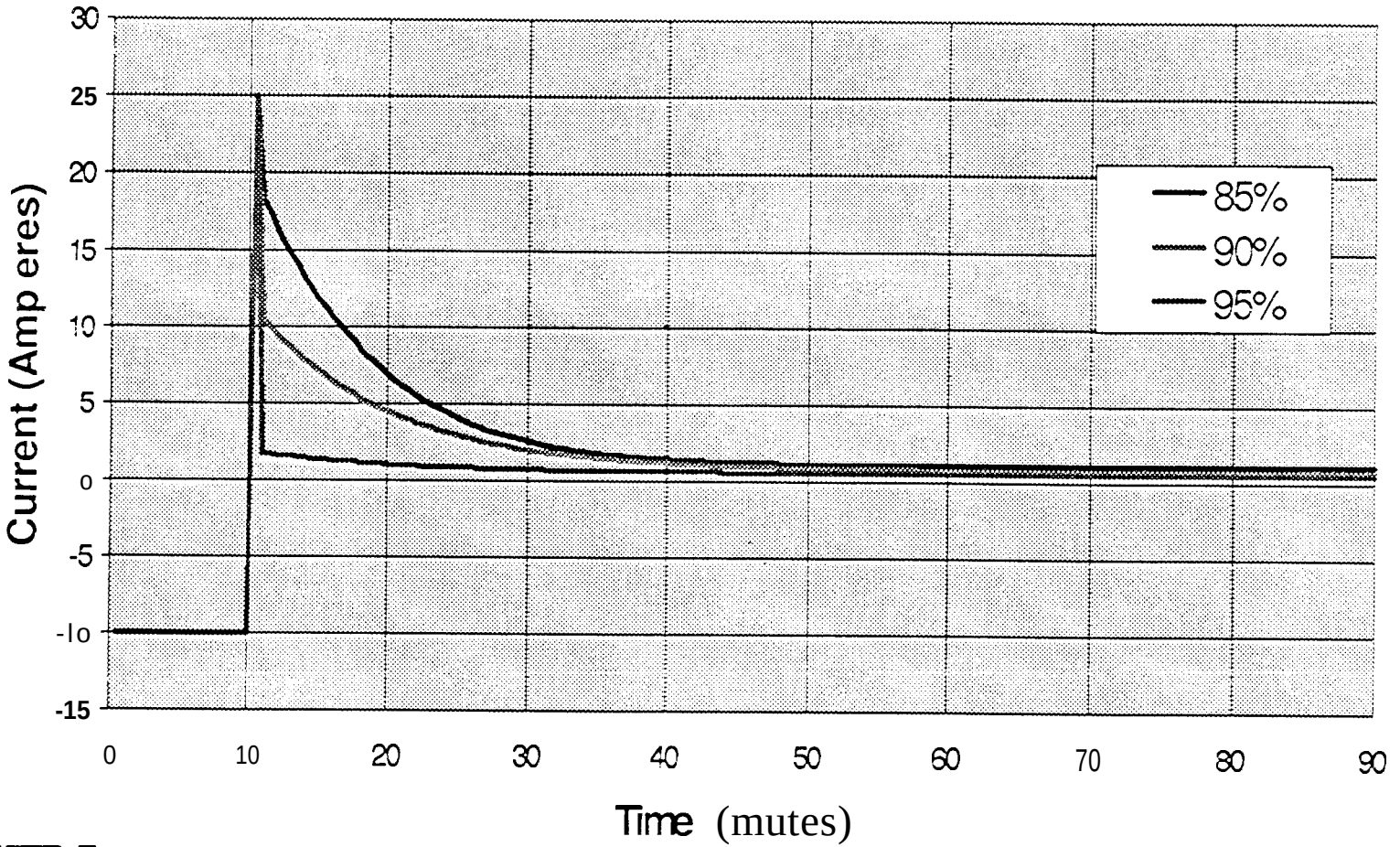
APPLICATION OF FIRST PRINCIPLES MODEL TO SPACECRAFT OPERATIONS

POSITIVE ELECTRODE POTENTIALS FOR VARIOUS INTITIAL Cd SOC's



APPLICATION OF FIRST PRINCIPLES MODEL TO SPACECRAFT OPERATIONS

CURRENTS FOR VARIOUS INITIAL SOC's OF Cd ELECTRODE



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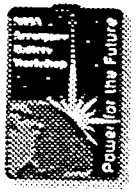
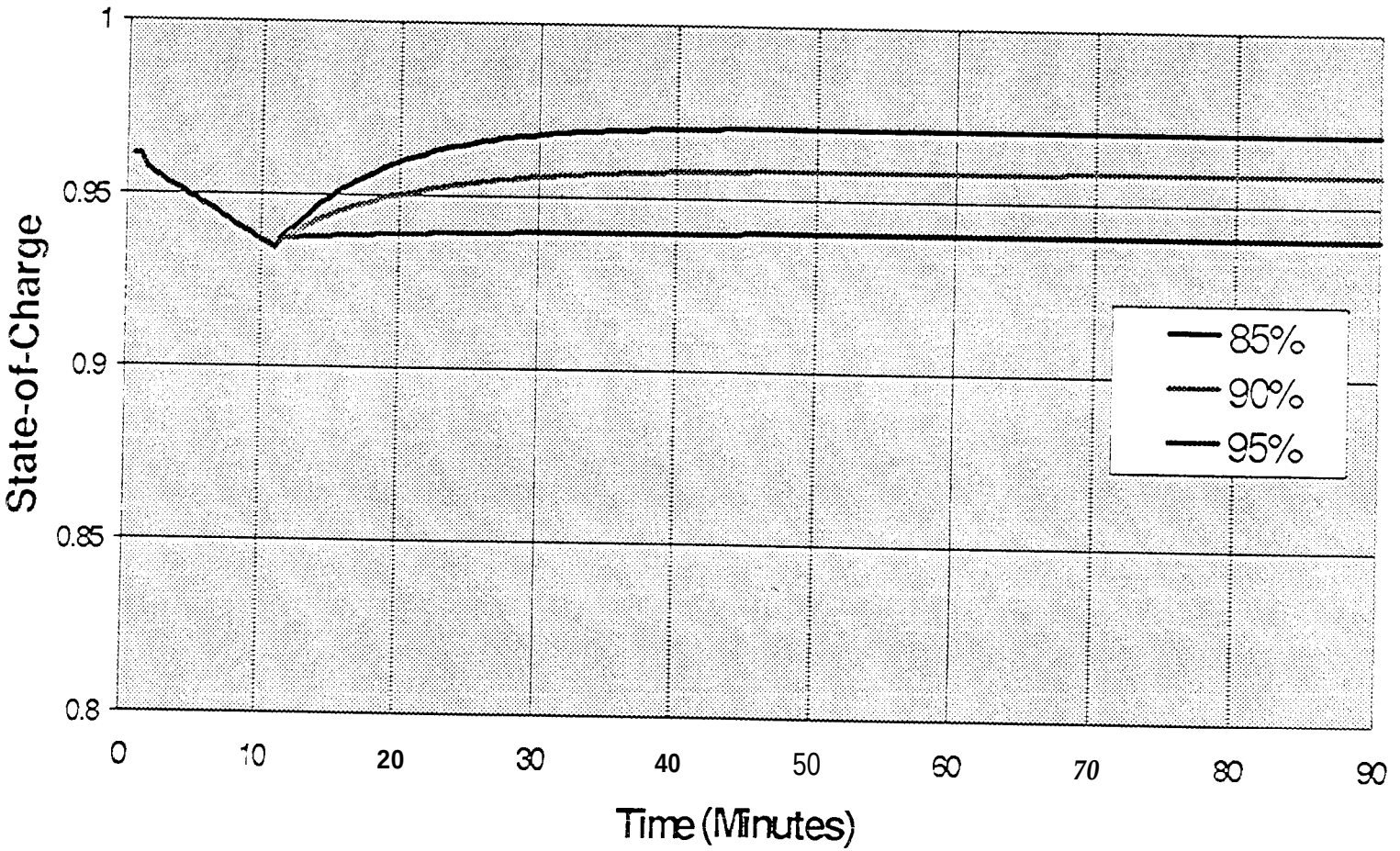


POSITIVE ELECTRODE SOC's FOR VARIOUS INITIAL Cd SOC's



NICKEL ELECTRODE FADING STUDIES

BASED ON INTERPHASE CONVERSION

AND CHANGES IN MORPHOLOGY / CONDUCTION

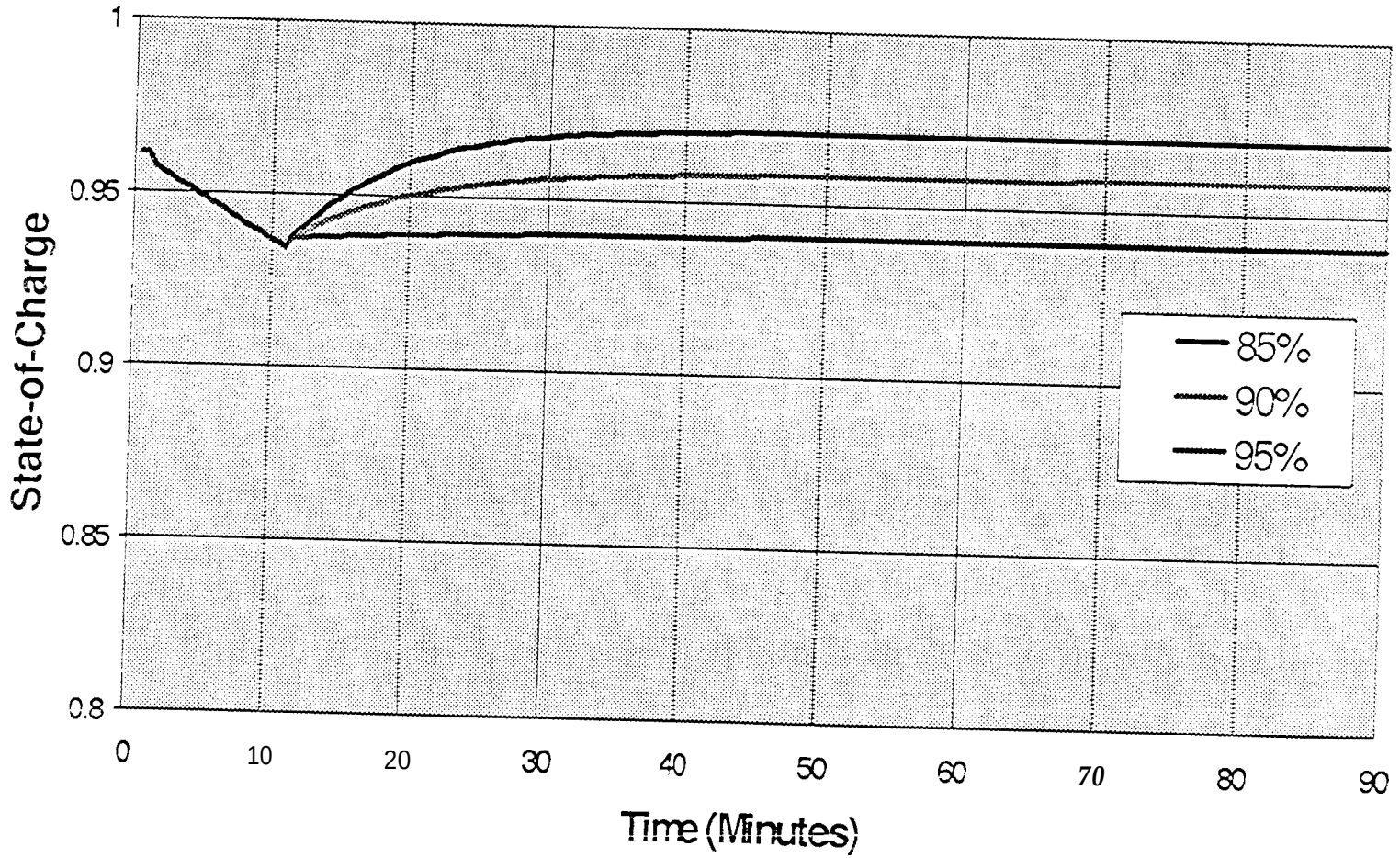
TOPEX 40% DOD CRANE LIFE TEST DATA USED FOR COMPARISON

ONLY POSITIVE ELECTRODE CHANGED IN THIS SECTION

SIMULATION OF VOLTAGE FADING OVER LIFE ACHIEVED

SECOND PLATEAU BEHAVIOR INCREASES OVER LIFE

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



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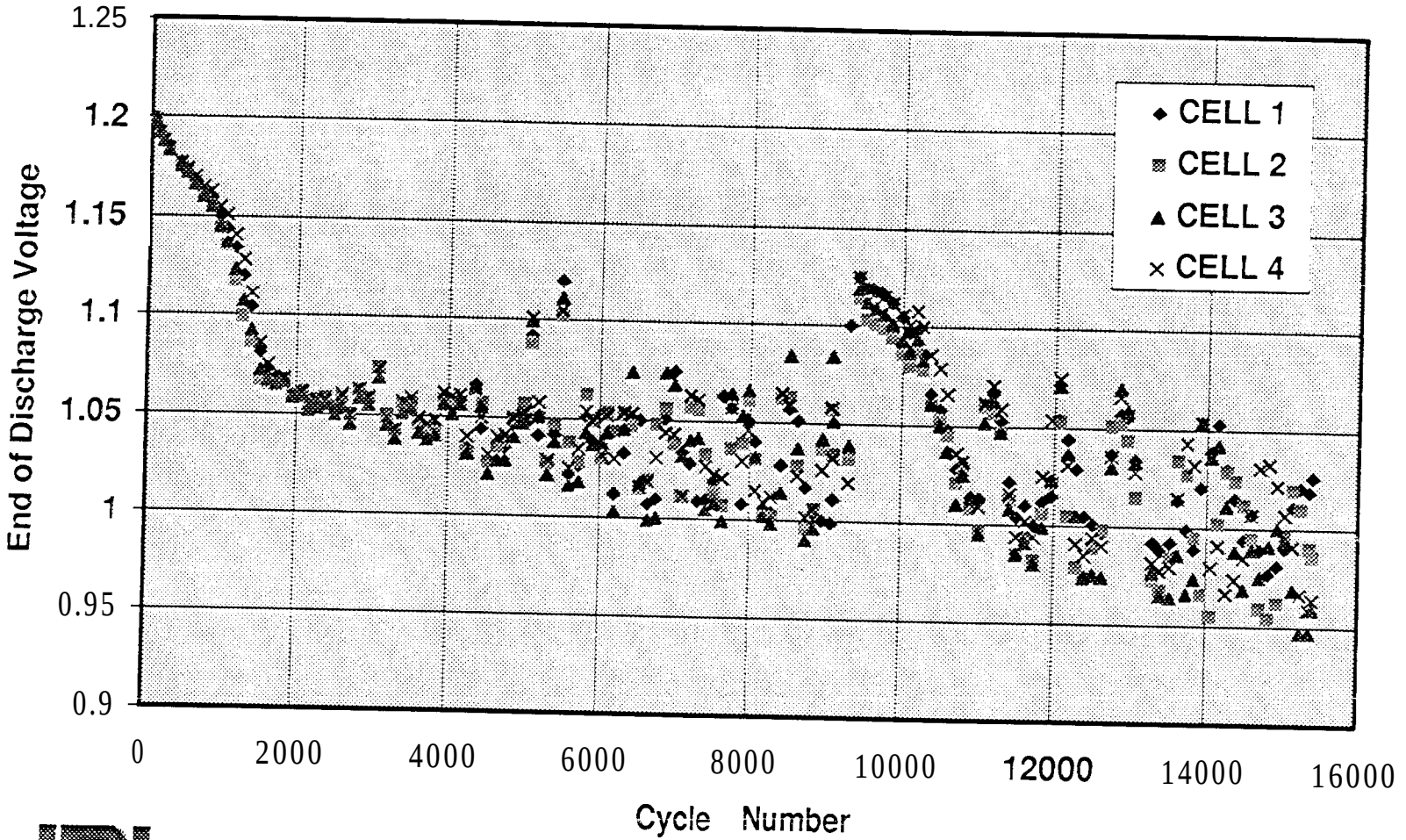
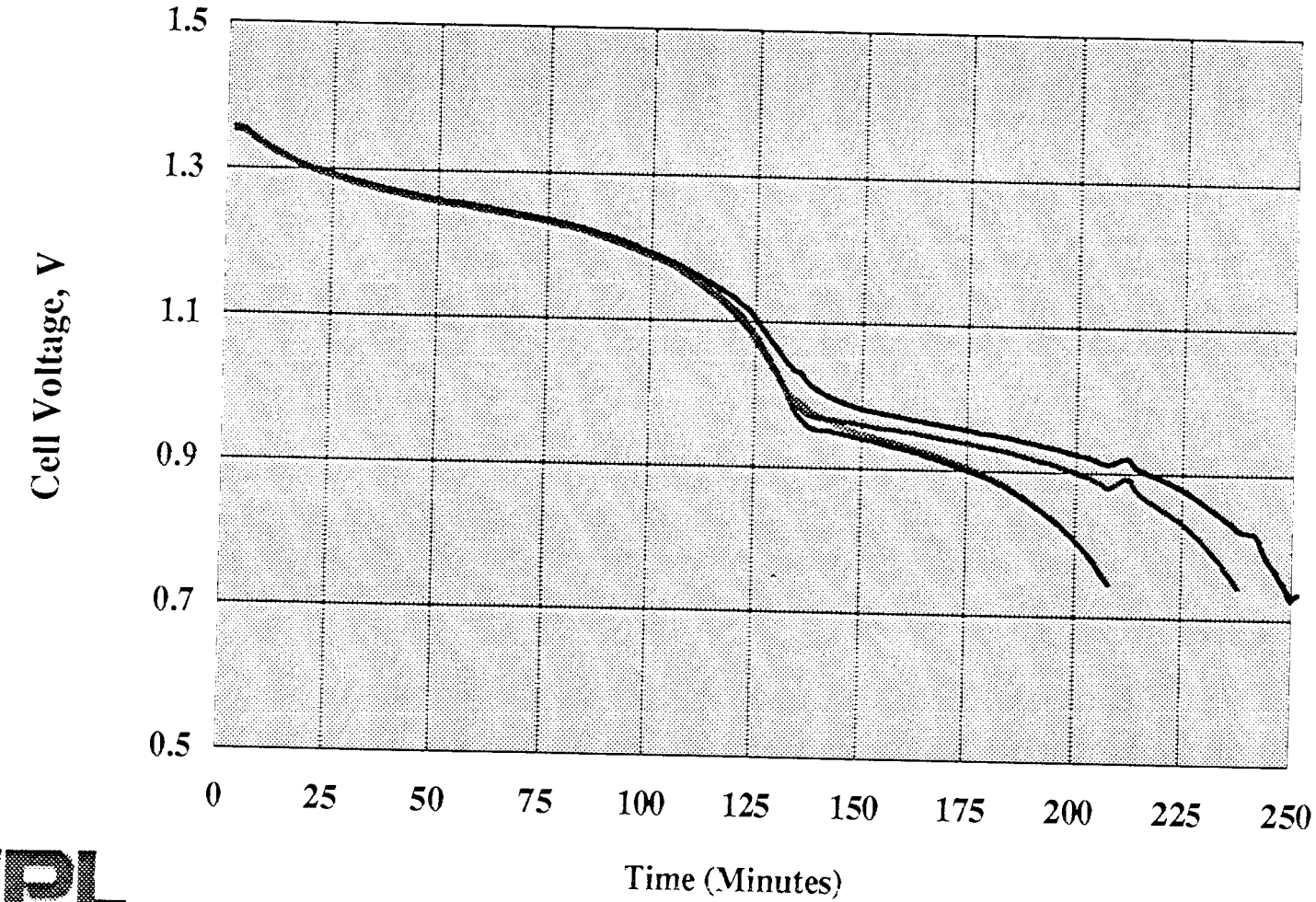
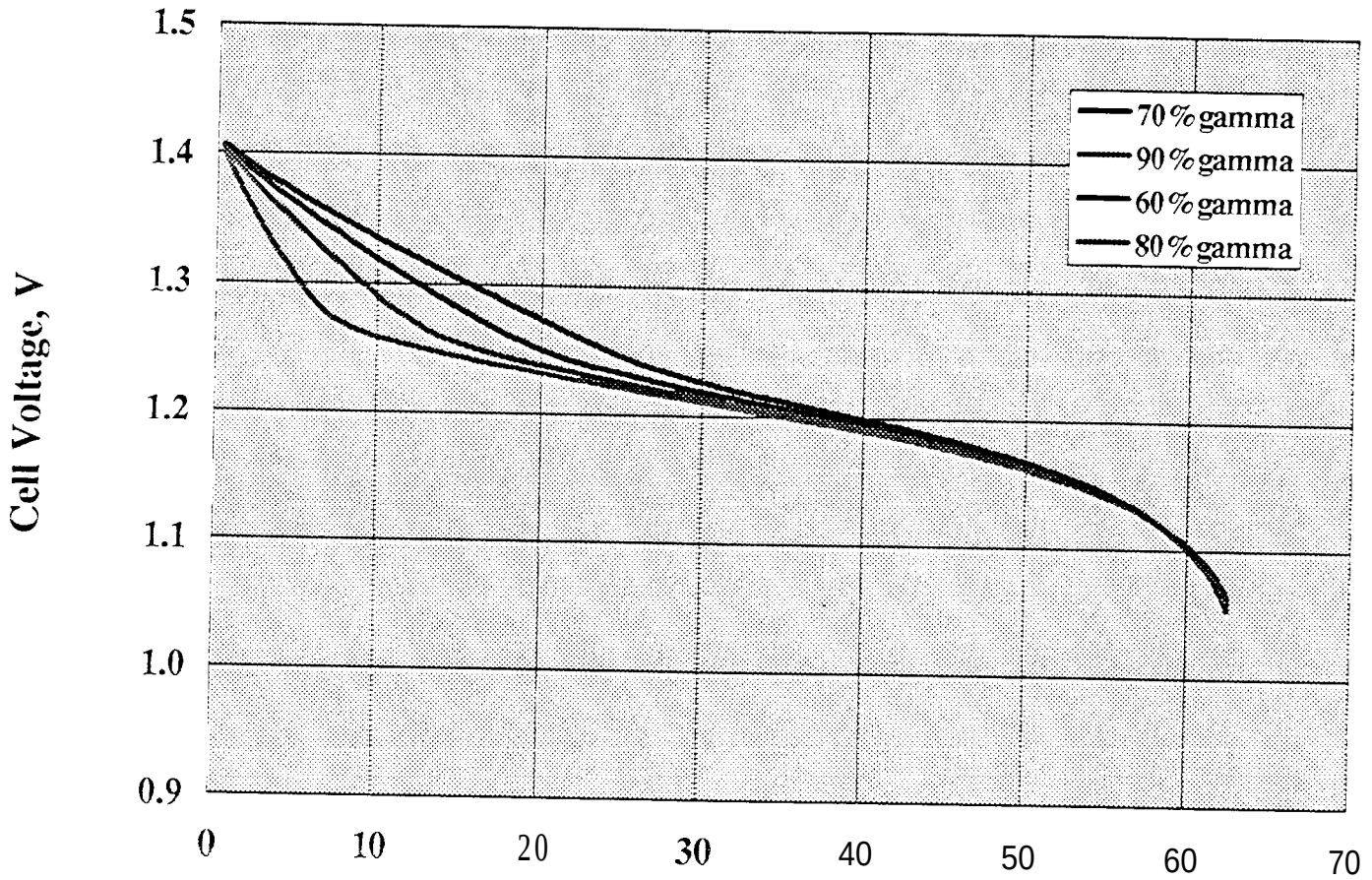
TOPEX NWSC Crane 40% DOD/ 20°C Life Test



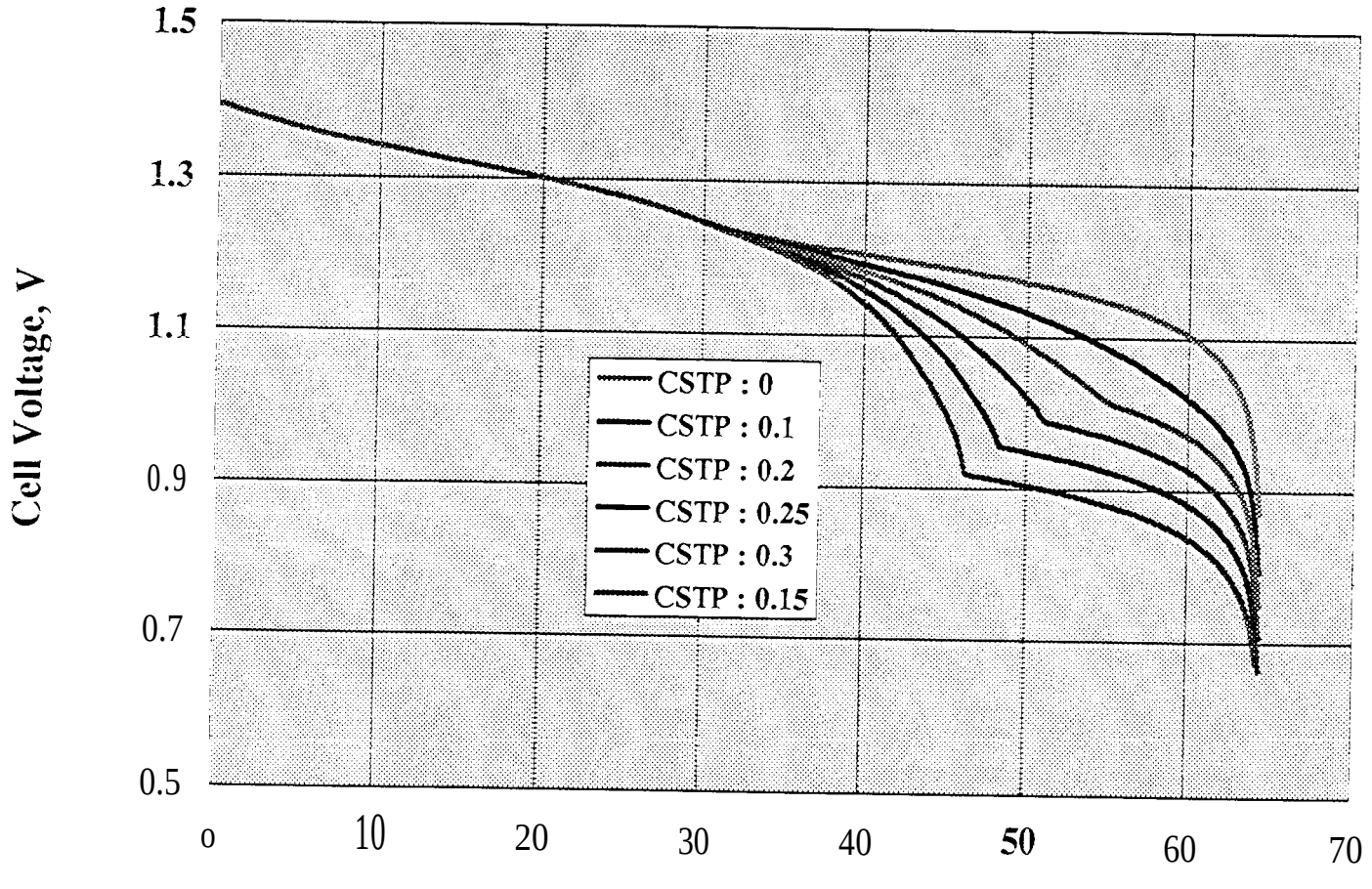
Post Life Test Discharge: Crane Topex Test



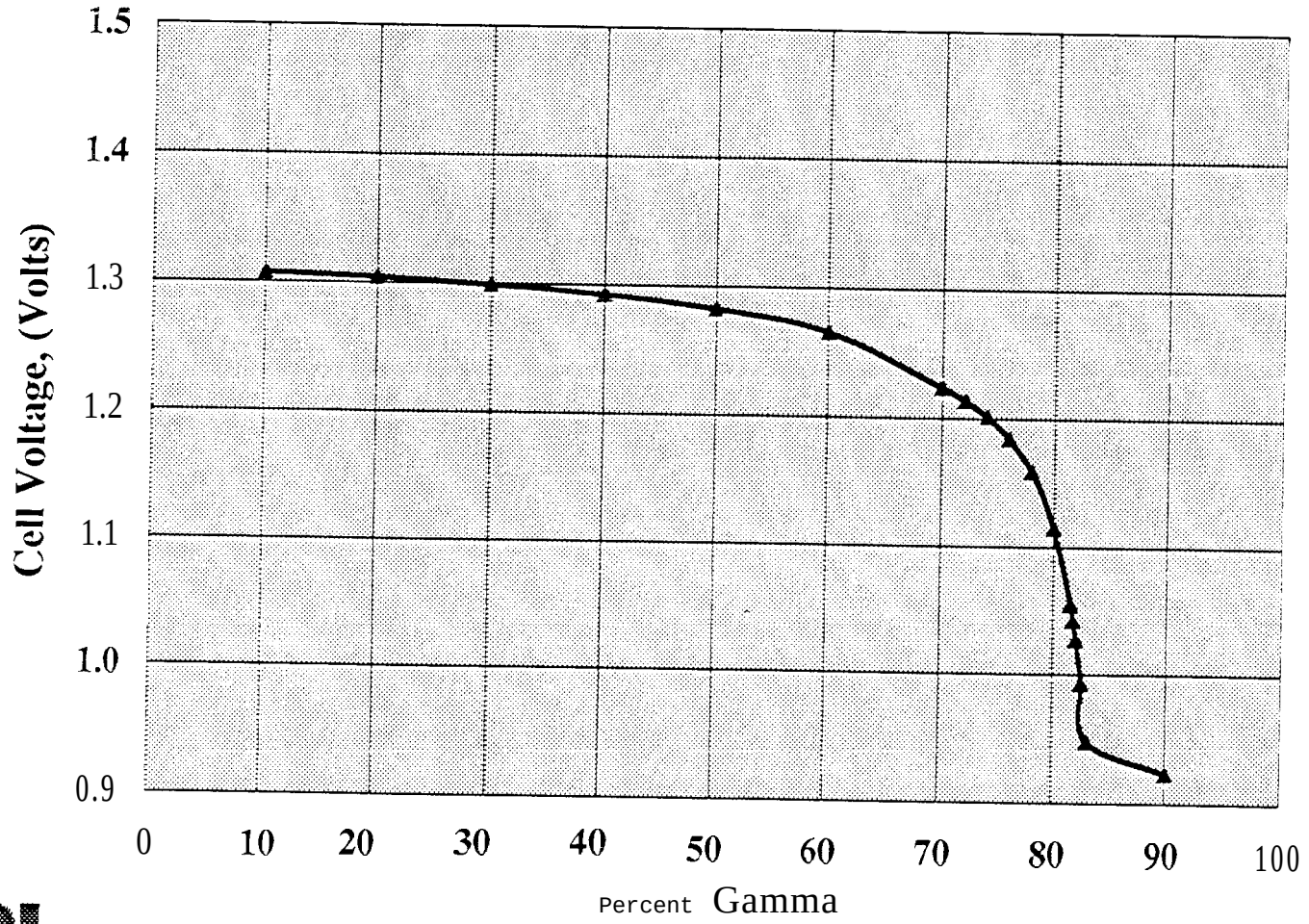
Post Life Test Discharge: Crane Topex Test



Effect of Conductivity Mixing Parameter (cstp)



Effect of Gamma Fraction on 40 % DOD LEO EON Voltage



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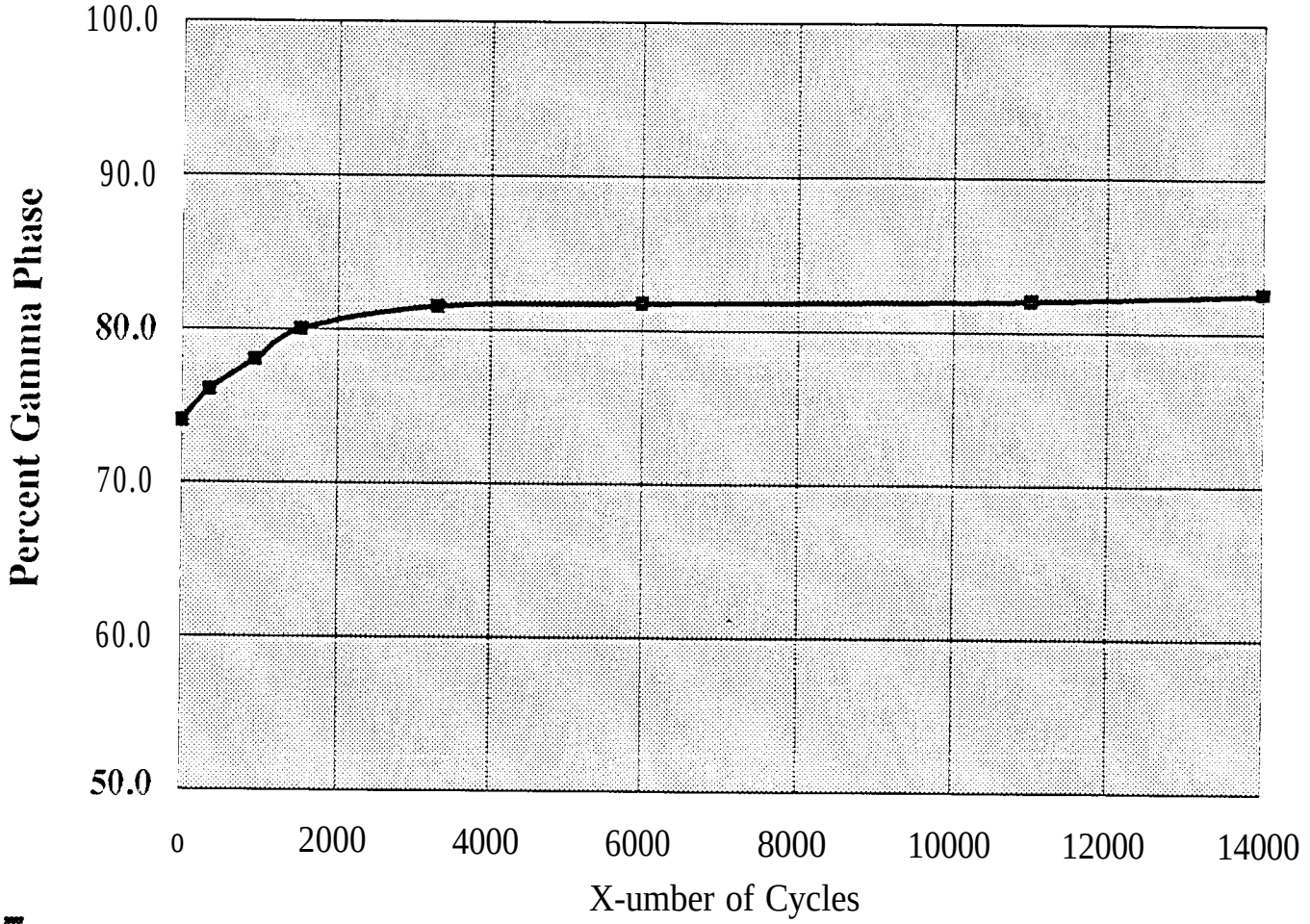
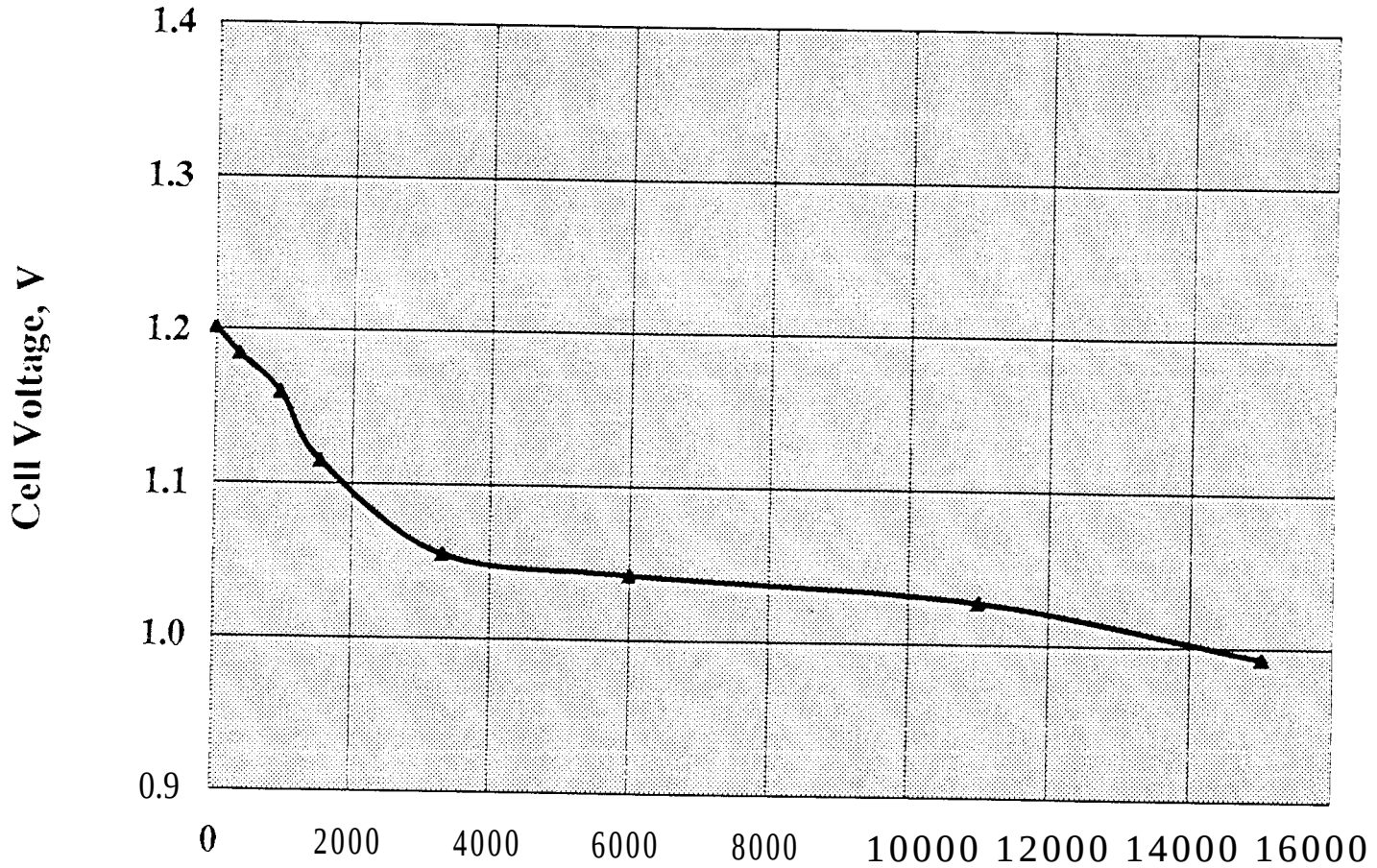
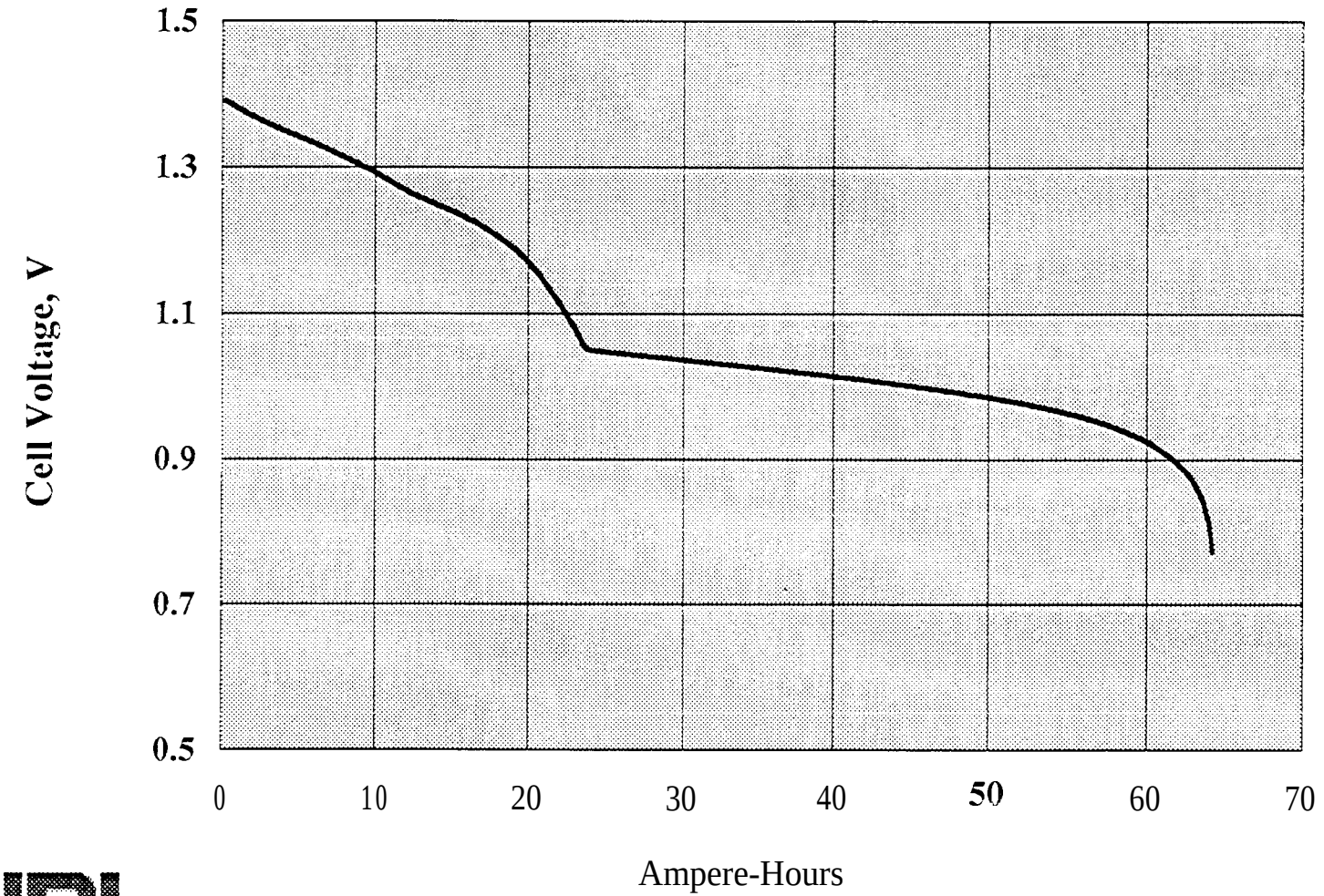
Estimated Gamma Fraction For Life Test



Predicted EON **Voltages** For Various Percent Gamma Phase



Predicted Discharge Voltage For Cycled Ceil



CONCLUSIONS

BI-PHASIC **NICKEL ELECTRODE EXPLAINS** MANY **BEHAVIORS**

VARIATION IN HYDROGEN PRECHARGE IN NIH2 **CELLS**

REDUCTION OF OVERCHARGE PROTECTION IN NICD CELLS

ONSET **OF NEGATIVE LIMITED BEHAVIOR**

CELL DIVERGENCE ON **LEO CYCLING**

EON VOLTAGE FADING ON **LEO CYCLING**

DEVELOPMENT OF SECOND PLATEAU ON **CYCLING**