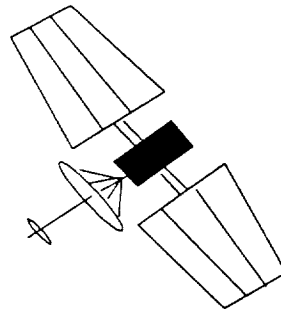


EAGLE-PICHER INDUSTRIES, INC.  
JOPLIN, MO

Advanced Systems Department

NICKEL-HYDROGEN GROUP

# 2.5 INCH NICKEL-HYDROGEN DEVELOPMENT 1992 NASA BATTERY WORKSHOP

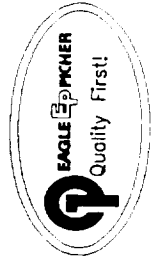


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## WHY DEVELOP A 2.5 INCH NICKEL-HYDROGEN CELL?

- \* Provide a Battery Alternative for the Small Satellite Market
- \* Provide High Reliability Product
- \* Simplify Charge Control Circuitry
- \* No Toxic Components
- \* Provide Better Performance Product for Same Price
- \* Anticipate Large Growth in Small Satellite Market



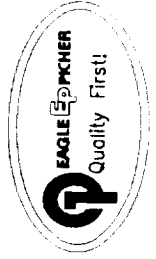
## 2.5 INCH NICKEL-HYDROGEN DEVELOPMENT HISTORY

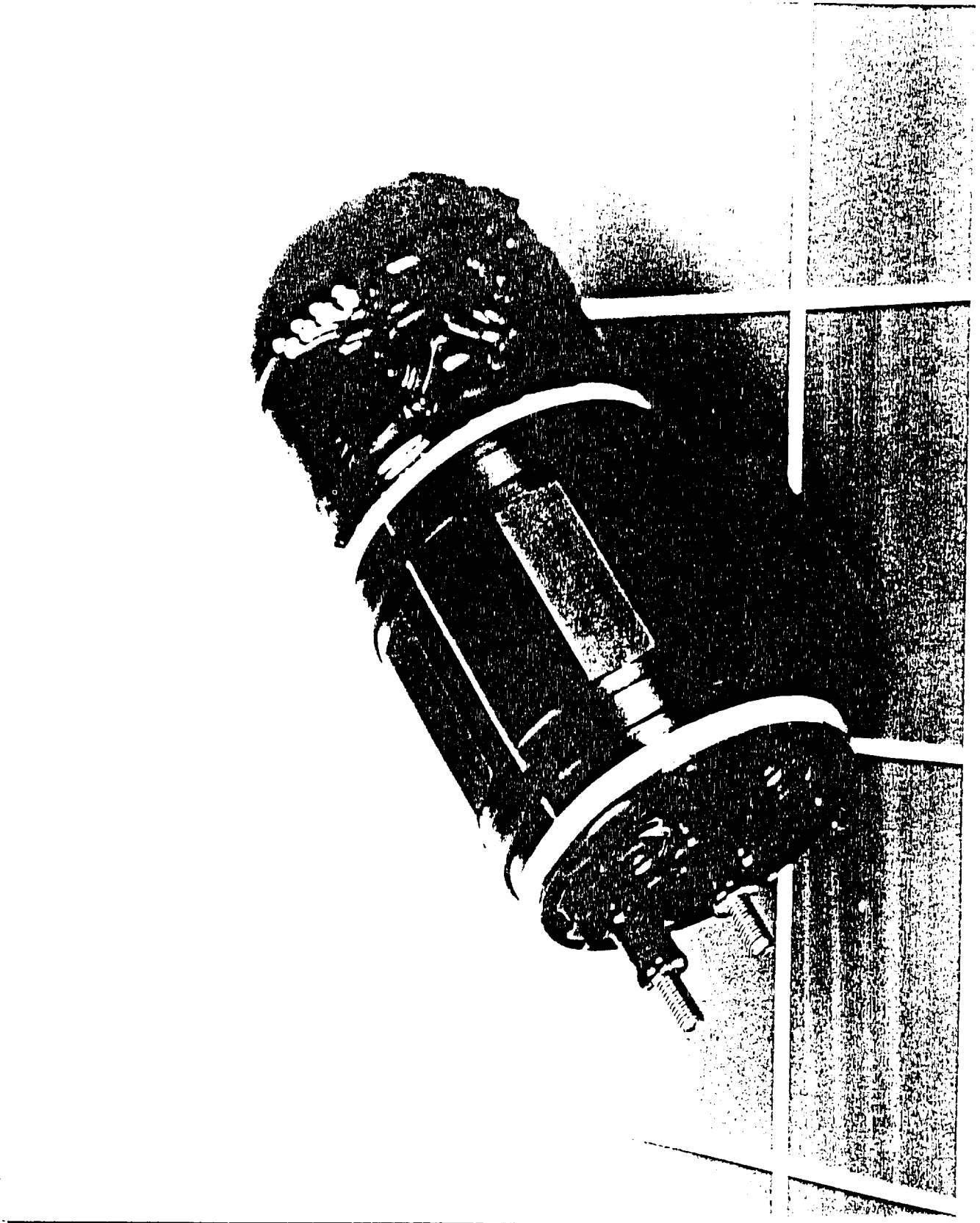
- \* Development Started in 1989 thru E.P. Internal Funding
- \* Development Went Thru three stages: Feasibility, prototype, and Production
- \* Main Driver Being Cost and Maintaining High Reliability
- \* On December 18, 1990 Started working with Orbital Sciences Corporation on Battery Development for APEX and SEASTAR Small Sat programs



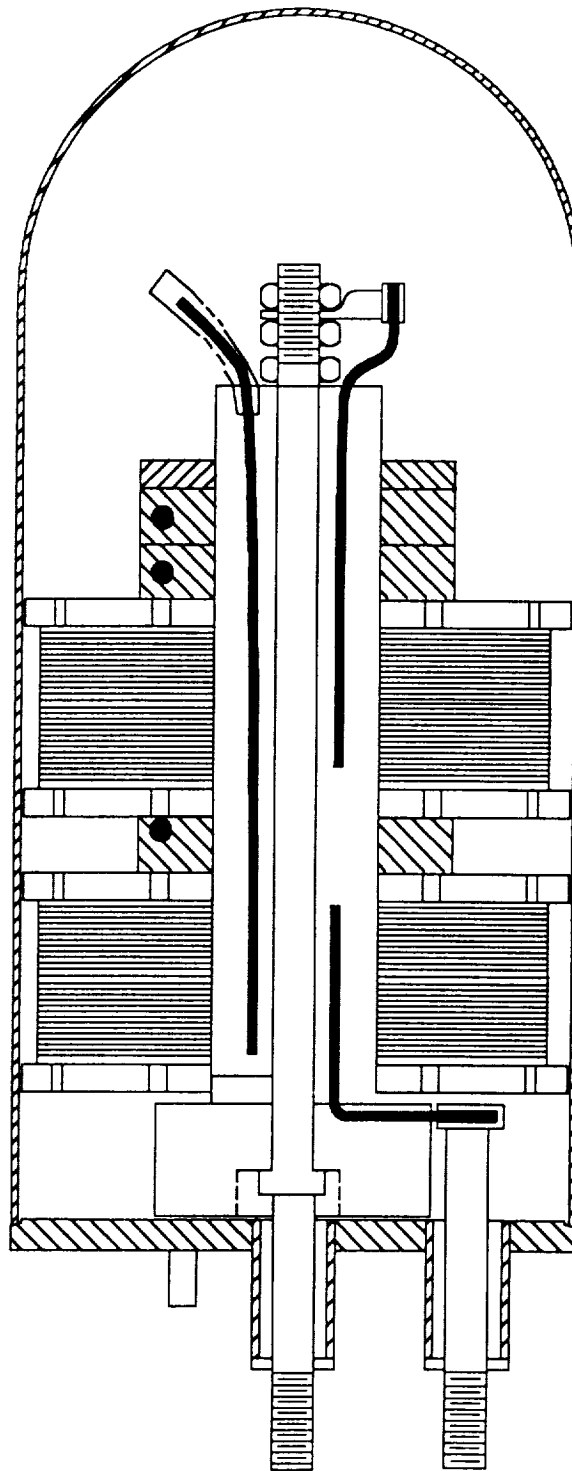
## 2.5 INCH NICKEL-HYDROGEN DEVELOPMENT HISTORY

- \* Delivered the following Flight Qualified Hardware (6AH DESIGN)
  - 20 Flight Qualified Cells                      JANUARY 15, 1991
  - 4- 10 CELL FLIGHT BATTERIES              JULY 9, 1992
  - 4 Battery Spare Cells                          Sept 10, 1992
  
- \* Contracted with Orbital Science in April 92 to provide Battery Cells for the  
Orbcomm Program Delivery Scheduled for March 5, 1992
  
- 10AH Design
  
- \* In negotiations on two additional Aerospace programs .

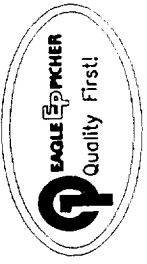
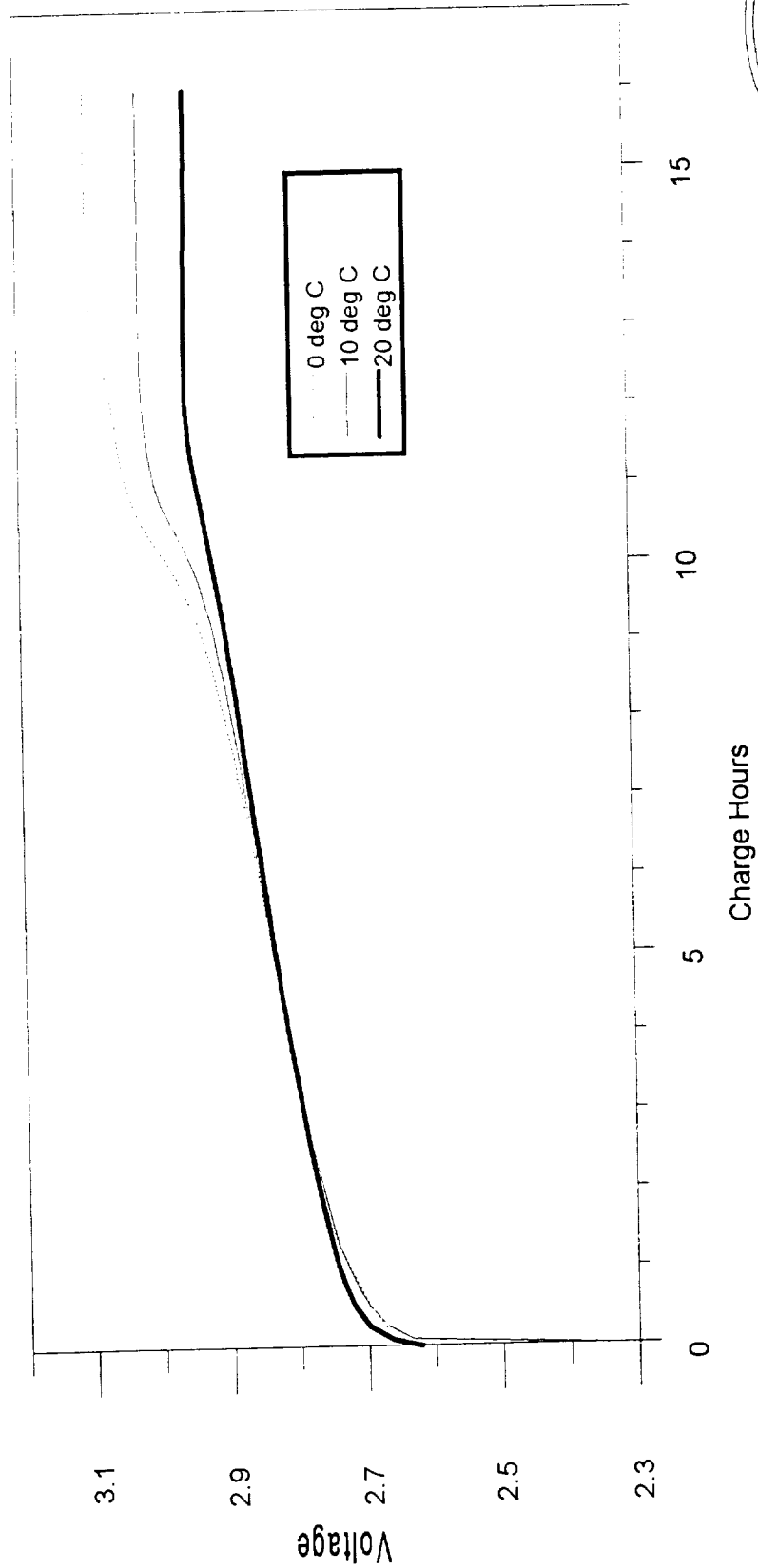




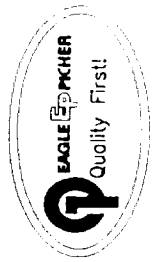
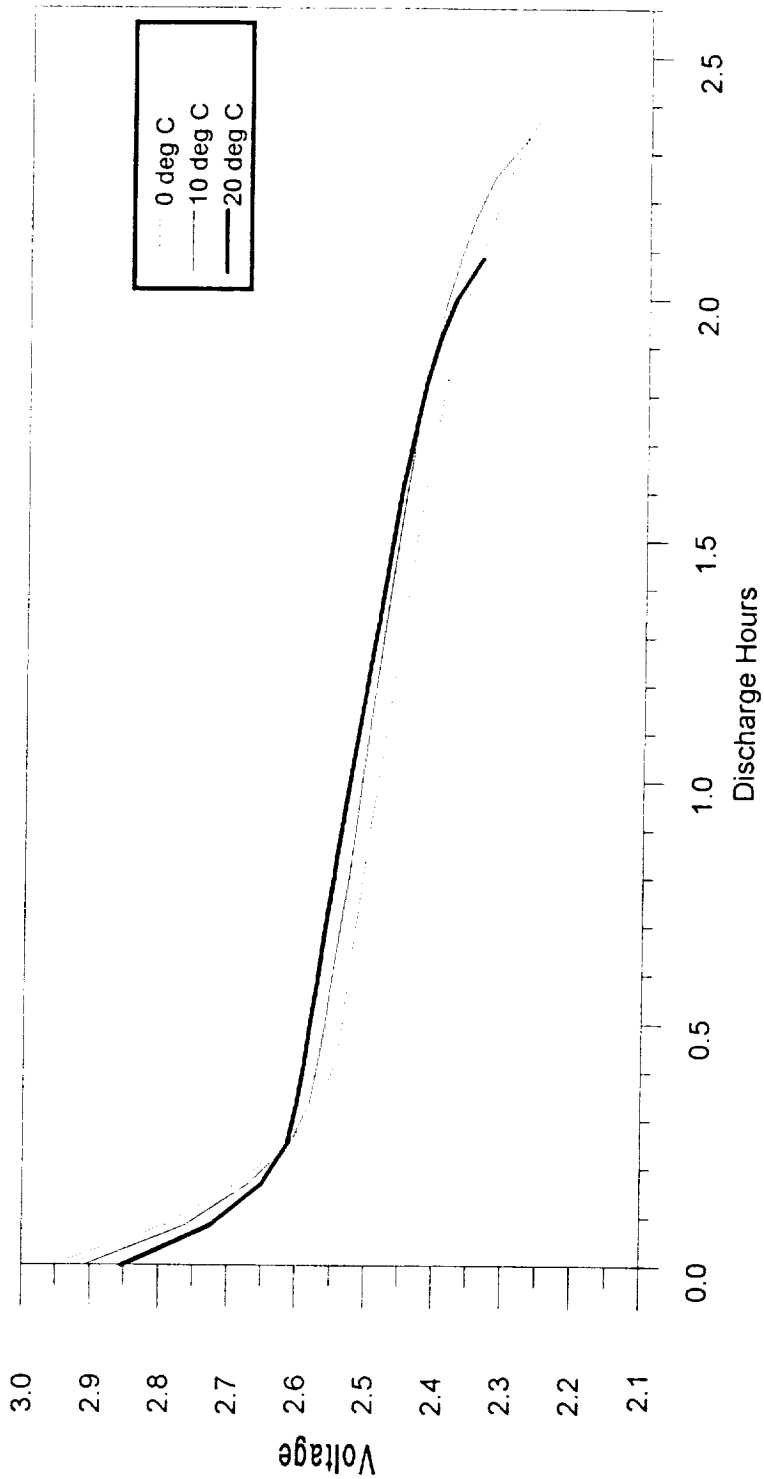
## RNHC-6-1 CELL DESIGN



# RNHC-6-1 CHARGE VOLTAGE AT 0.6A



## RNHC-6-1 DISCHARGE VOLTAGE AT 3.0 AMPS





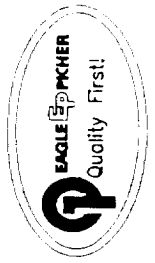
## RNHC-6-1 CELL QUALIFICATION TESTING

- \* Cell proof pressure to 1.5 times MEOP
- \* Cell cycle testing to 85,000 cycles at MEOP
- \* Cell Burst testing > 4/1 safety factor
- \* Cell Vibration test to 9 GRMS
- \* Thermal Vacuum Testing 120 hrs
- \* Performance testing at 0,10,20 degree C  
3.0 amp discharge



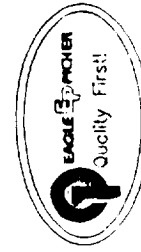
## FLIGHT UNIT TESTING

- \* Pressure Testing 1.5\* MEOP
- \* Leak Check
- \* X Ray
- \* OC Capacity Test
- \* 10C Capacity Test
- \* 10C Charge Retention Test
- \* 20C Capacity Test
- \* Impedance Check



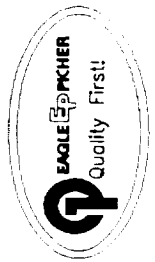
## RNHC-6-1 TECHNICAL DATA

Rated Capacity.....	6 AH
Nominal Voltage.....	2.5 Volts
Cell Mass.....	633 Grams
Diameter.....	6.48 cm
Length.....	17.15 cm
Capacity to 2.0 Volts.....	7.1 AH
Specific Energy.....	28 WH/KG
Energy Density.....	39.2 WH/L
Operating Pressure.....	400 PSIG
Safety Factor.....	5/1
Cell Case.....	304LSS
Separator.....	Zircar
Positive Electrode.....	Slurry



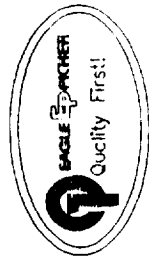
## RNHC-10-1 TECHNICAL DATA

Rated Capacity.....	10 AH
Nominal Voltage.....	2.5 Volts
Cell Mass.....	700 Grams
Diameter.....	6.48 cm
Length.....	18.62 cm
Capacity to 2.0 Volts.....	11.8 A
Operating Pressure.....	500 PSIG
Safety Factor.....	5/1
Cell Case.....	Inconel
Separator.....	Zircar
Positive Electrode.....	Slurry



## Technical Data for SAR-10027 Battery

Rated Capacity.....	6AH
Nominal Mass.....	25.0 Volts
Battery Mass.....	8467 Grams
Length.....	40.6 cm
Width.....	39.4 cm
Height.....	8.3 cm
Capacity to 2.0 V @ 10C.....	7.1 AH
Specific Energy.....	21.20 Wh/Kg
Energy Density.....	13.5 Wh/L
Vibration.....	9.0 GRMS
Thermal - Vac.....	120 hr
Thermistors.....	2
Heaters.....	2
Electrical Isolation.....	Two Levels.



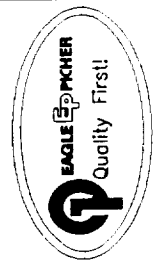
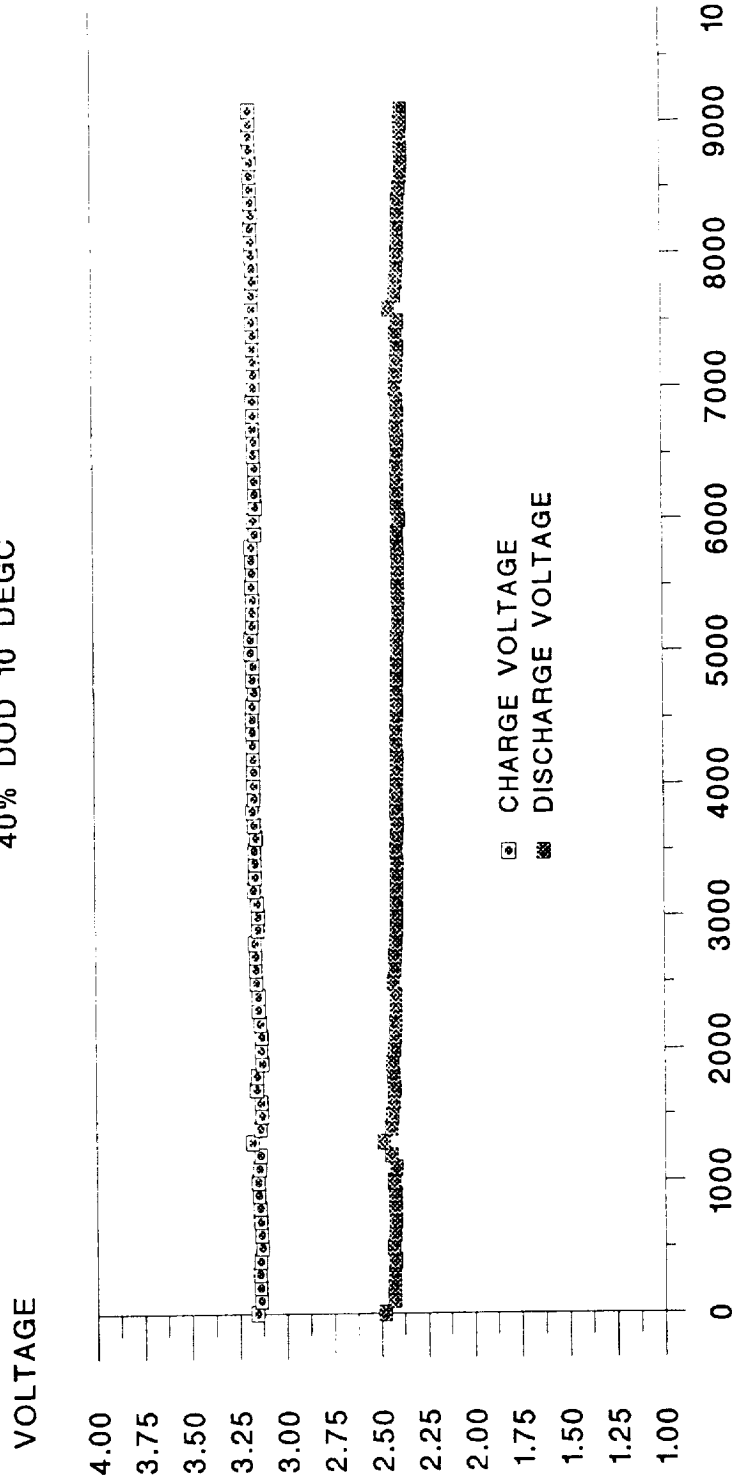
## SAR10027 BATTERY TESTING

- \* Charge/ discharge capacity test at 20 degree C
- \* Vibration test to 9Grms (random)
- \* Thermal-Vaccum test temp cycle for 120 hrs



# RNHC-10-1 LIFE TEST AS OF 10/31/92

40% DOD 10 DEGC



## CONCLUSION

Successfully developed and manufactured a 6AH and a 10 AH 2.5 Inch CPV  
Nickel - Hydrogen Pressure Vessel for Aerospace and Terrestrial Application

The scheduled flight for the 6 AH cell is JULY 1993

