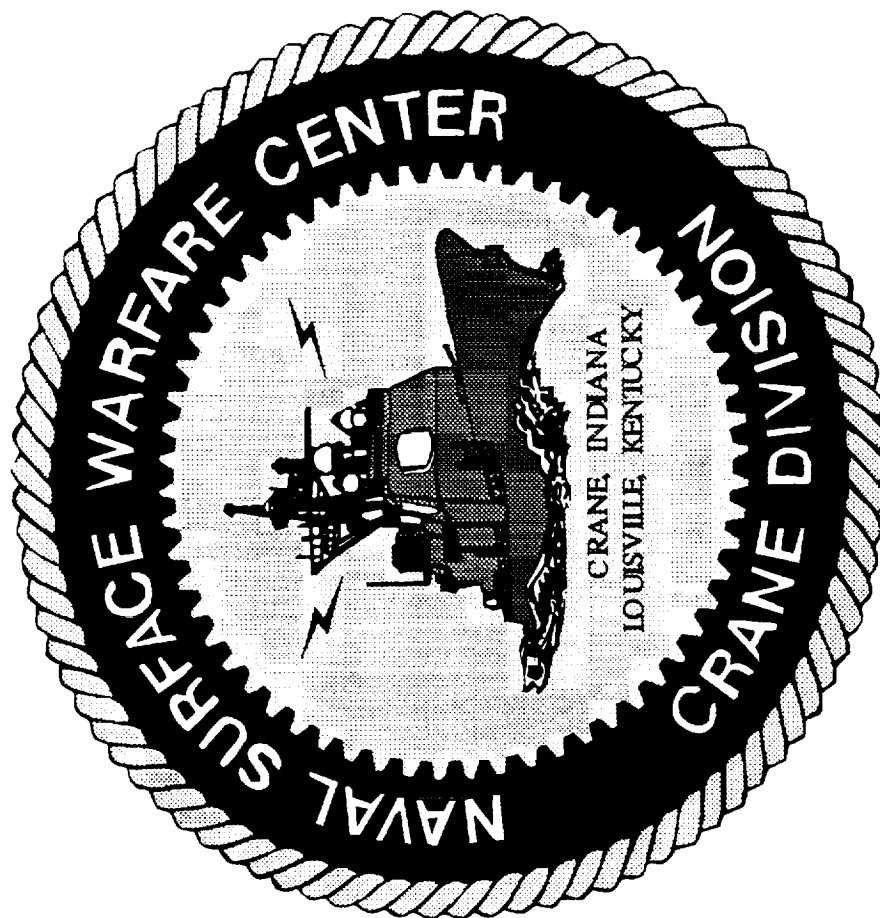


N94- 28122

AF Ni-Cd Cell Qualification Program



S. Hall and H. Brown NSWC CRANE  
G. Collins and W. Hwang Aerospace Corporation

PRECEDING PAGE BLANK NOT FILMED

# AIR FORCE NI-CD PROGRAM OVERVIEW OF TEST PROGRAM



## PURPOSE

GENERIC QUALIFICATION OF AEROSPACE NICKLE-CADMIUM CELLS

MULTIPLE MANUFACTURES  
MULTIPLE DESIGNS  
INCLUDES CELLS FROM PREVIOUS PROGRAM  
HIGH AND LOW ORBIT LIFE CYCLING

CHARACTERIZE BEGINNING OF LIFE PERFORMANCE



# STRESS TEST

## 6351A

**TYPE**

50 A/H NI-CD, HUGHES

**TEMPERATURE**

20 DEGREES CENTIGRADE

**ORBIT**

100 MINUTES

**DISCHARGE**

36.0 AMPS FOR 34 MINUTES, 40%DOD

**CHARGE**

25.0 AMPS WITH V/T TAPER AT V/T 7.5 (1.464 V/C)



6352A

TYPE

50 A/H NI-CD, HUGHES

TEMPERATURE

5 DEGREES CENTIGRADE

ORBIT

96 MINUTES

DISCHARGE

25.0 AMPS FOR 30 MINUTES, 25%DOD

CHARGE

25. AMPS WITH V/I TAPER AT V/I 5.5 (1.458 V/C)



RECONDITIONED AT SIX MONTH INTERVALS

6352A

DISCHARGE AT C/2 TO 1.10 VOLT FIRST CELL

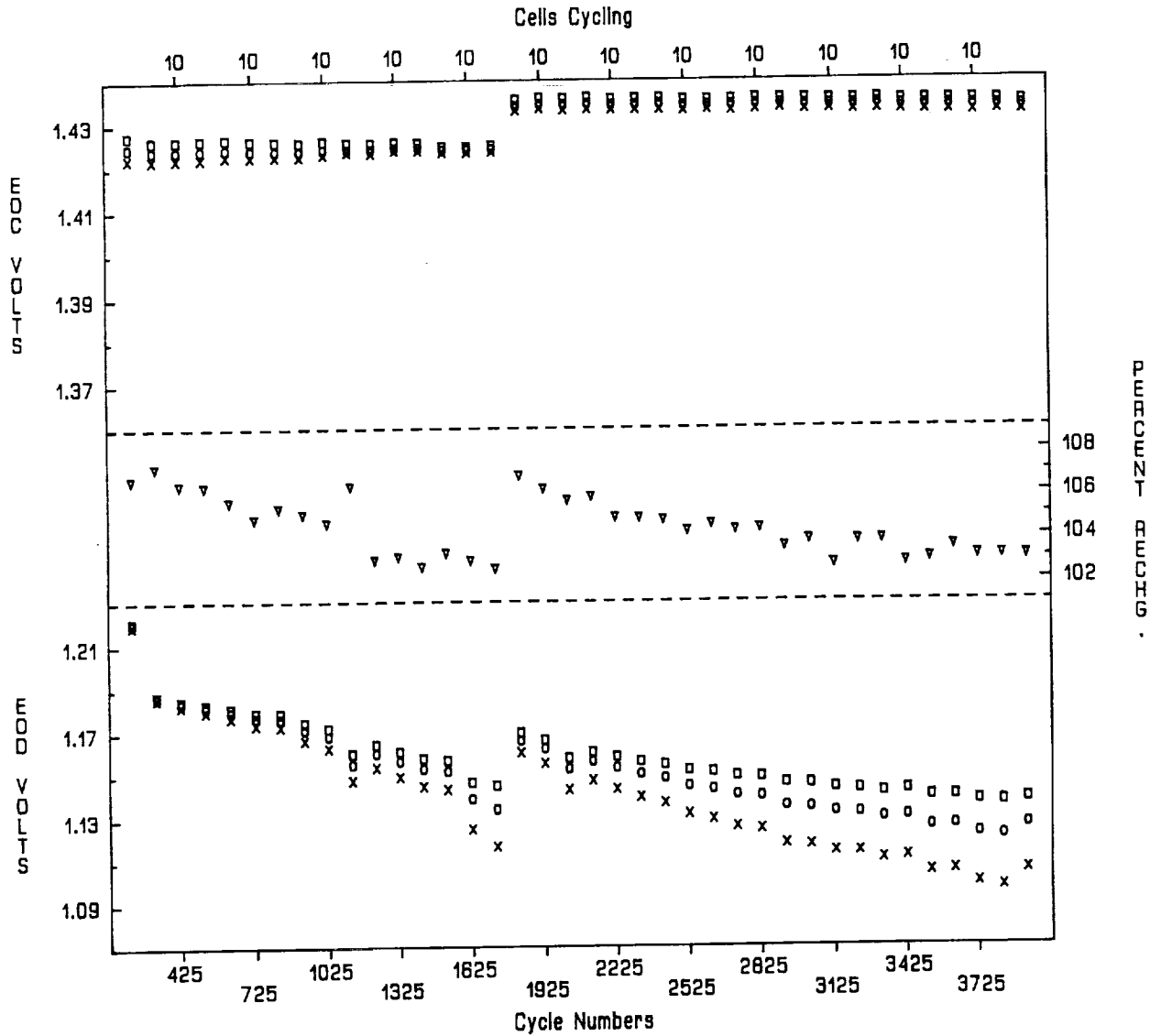
MONTHS	A/HO
6	36.3
12	33.8
18	38.0

ANNUAL TRENDPLOT

Pack: 6321H    Manf: HUGHES    21.0 AH  
 Orbit: LEO    Temp (C): 20    DOD(%): 40.0  
 Discharge(Amp/Hrs): 15.0/0.56    Charge(Amp/Hrs): 10.5/1.12

Plot area #1 -- keys:    Right-side:  
 Left-side:    OFF  
 o -- High Cell  
 o -- Average  
 x -- Low Cell  
 Plot area #2 -- keys:    Right-side:  
 Left-side:    OFF  
 v -- PERCENT RECH  
 Plot area #3 -- keys:    Right-side:  
 Left-side:    OFF  
 o -- High Cell  
 o -- Average  
 x -- Low Cell

TEST DATA AS OF OCTOBER 23, 1993



1. START LIFE-CYCLING, V/T 5.5 (1.424 V/C).
2. CYCLE 1851, V/T INCREASED TO 6.0 (1.434 V/C).



## CONCLUSIONS OF RESULTS FOR "SUPER NICD" CELLS

---

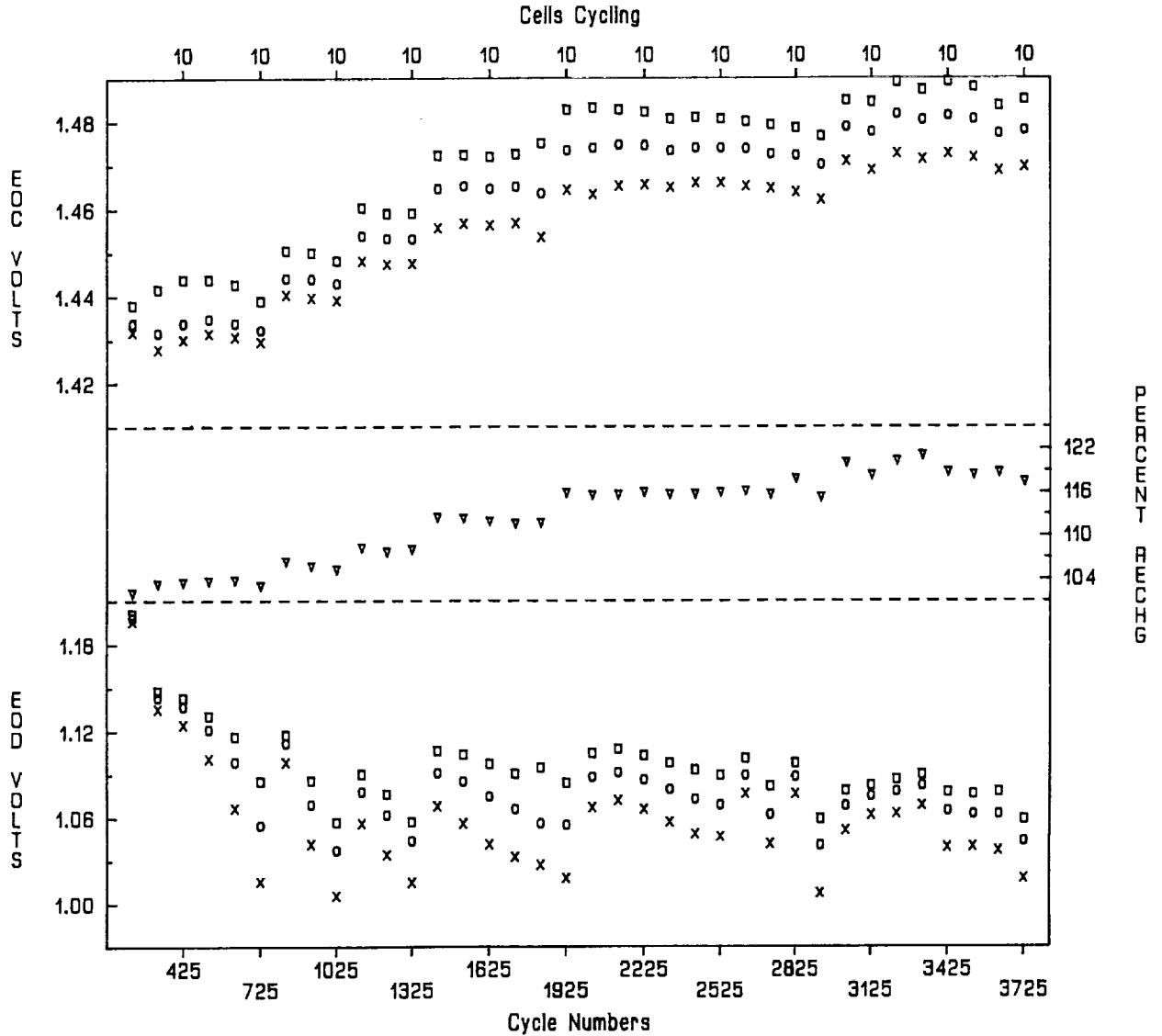
- \* THERE IS A STORAGE/HANDLING ISSUE
- \* 50 Ah, 40% DOD PACK HAS INCREASING EOCV DIVERGENCE
- \* BEGINNING OF LIFE CAPACITY FADE NOT DETRIMENTAL TO CYCLE LIFE

ANNUAL TRENDPLOT

Pack: 6350S    Manf: SAFT    50.0 AH  
 Orbit: LED    Temp (C): 20    DOD(%): 40.0  
 Discharge(Amp/Hrs): 35.3/0.56    Charge(Amp/Hrs): 25.0/1.12

Plot area #1 -- keys:    Right-side:  
 Left-side:    OFF  
 o -- High Cell  
 o -- Average  
 x -- Low Cell  
 Plot area #2 -- keys:    Right-side:  
 Left-side:    OFF  
 v -- PERCENT RECH  
 Plot area #3 -- keys:    Right-side:  
 Left-side:    OFF  
 o -- High Cell  
 o -- Average  
 x -- Low Cell

TEST DATA AS OF OCTOBER 23, 1993



1. START OF LIFE CYCLING, V/T 6.0 (1.434 V/C).
2. CYCLE #775, INCREASED TO V/T 6.5 (1.444 V/C) DUE TO LOW EOD'S.
3. CYCLE #1125, INCREASED TO V/T 7.0 (1.454 V/C) DUE TO LOW EOD'S.
4. CYCLE #1513, INCREASED TO V/T 7.5 (1.464 V/C) DUE TO LOW EOD'S.
5. CYCLE #2020, INCREASED TO V/T 8.0 (1.474 V/C) DUE TO LOW EOD'S.
6. CYCLE #3076, INCREASED TO V/T 8.5 (1.484 V/C) DUE TO LOW EOD'S.

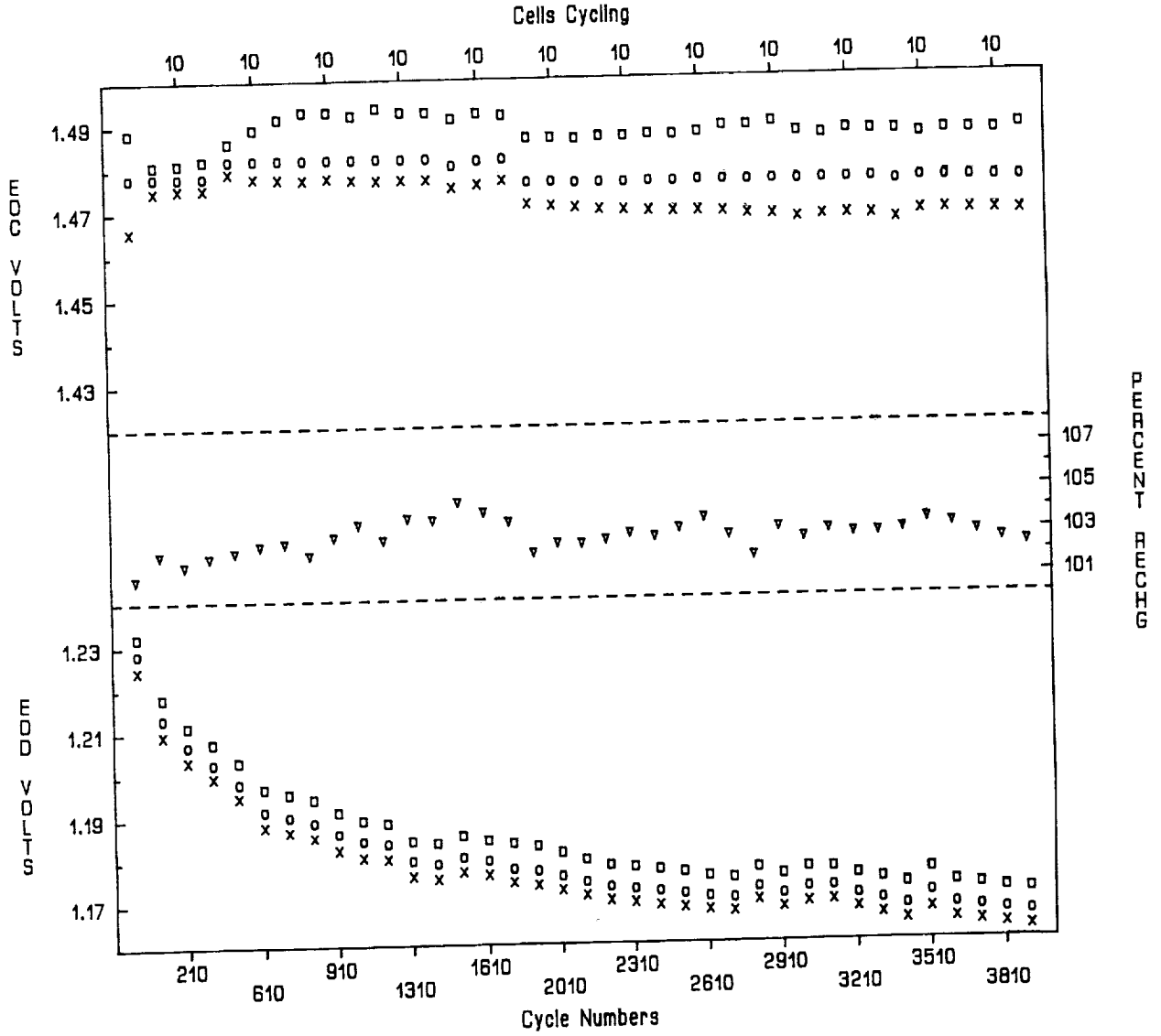


ANNUAL TRENDPLOT

Pack: 6351S    Manf: SAFT    50.0 AH  
 Orbit: LEO    Temp (C): 0    DOD(%): 25.0  
 Discharge(Amp/Hrs): 25.0/0.50    Charge(Amp/Hrs): 25.0/1.10

Plot area #1 -- keys:    Right-side: OFF  
 Left-side:    High Cell (o)    Average (o)    Low Cell (x)  
 Plot area #2 -- keys:    Right-side: PERCENT RECH (v)  
 Left-side: OFF  
 Plot area #3 -- keys:    Right-side: OFF  
 Left-side:    High Cell (o)    Average (o)    Low Cell (x)

TEST DATA AS OF OCTOBER 23, 1993



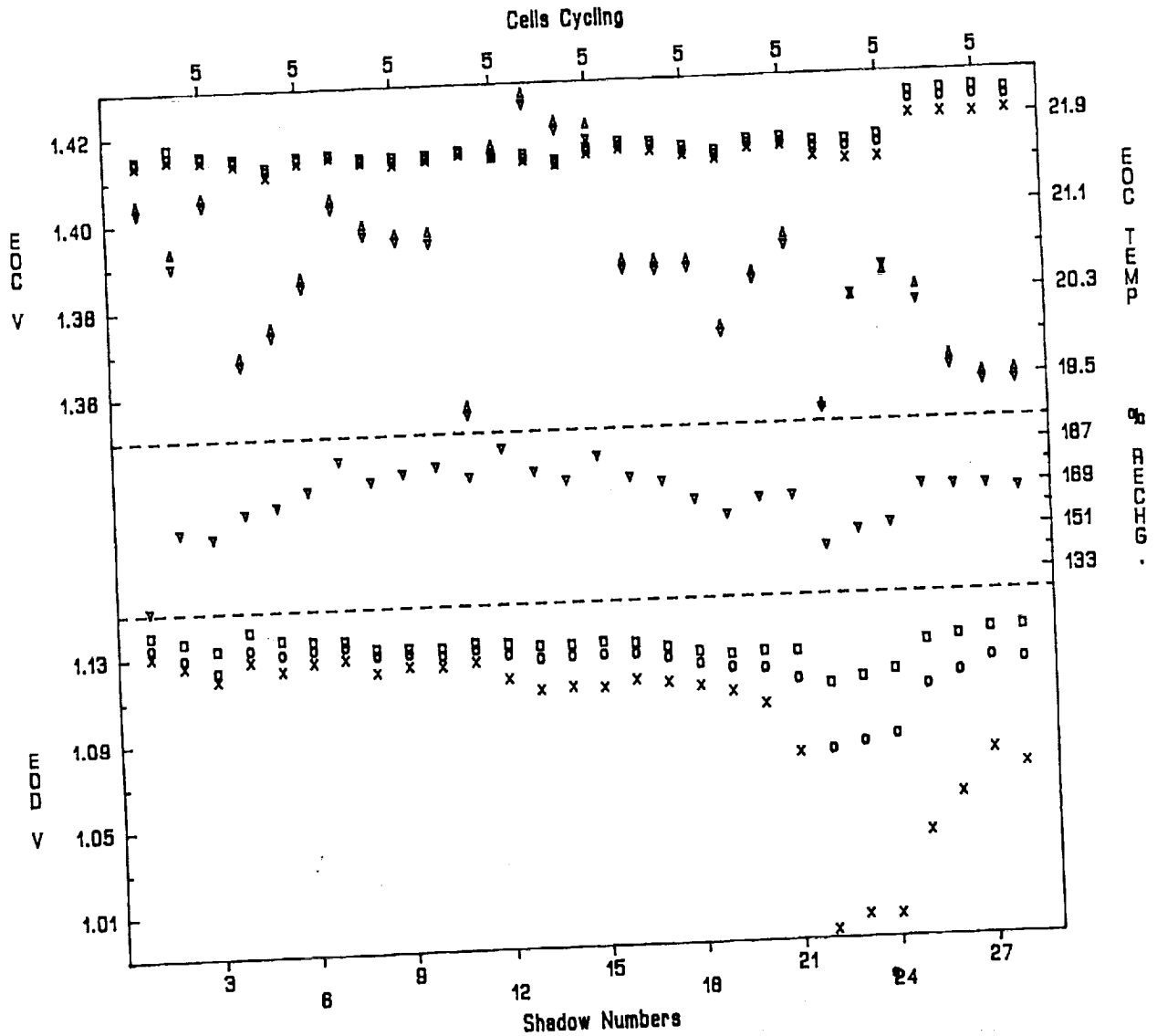
1. STARTED LIFE-CYCLING, V/T 6 (1.480 V/C).

\*\*\*GEO\*\*\* AIR FORCE  
 TREND OF MID SHADOW  
 Pack: 8224S    Manf: SAFT    24.0 AH  
 Orbit: GEO    Temp (C): 20    DOD(%): 80.0

DISCHARGE (16.0 AMPS).  
 CHARGE (2.4 AMPS) WITH 1.414 V/C

SHADOWS 1 THRU 28

Plot area #1 -- keys:  
 Left-side:    Right-side:  
 o -- High Cell    ▽ -- EOC TEMP  
 o -- Average    ▲ -- EOC TEMP  
 x -- Low Cell    ▾ -- EOC TEMP  
 Plot area #2 -- keys:  
 Left-side:    Right-side:  
 OFF    ▽ -- % RECHG.  
 Plot area #3 -- keys:  
 Left-side:    Right-side:  
 OFF    OFF  
 o -- High Cell  
 o -- Average  
 x -- Low Cell

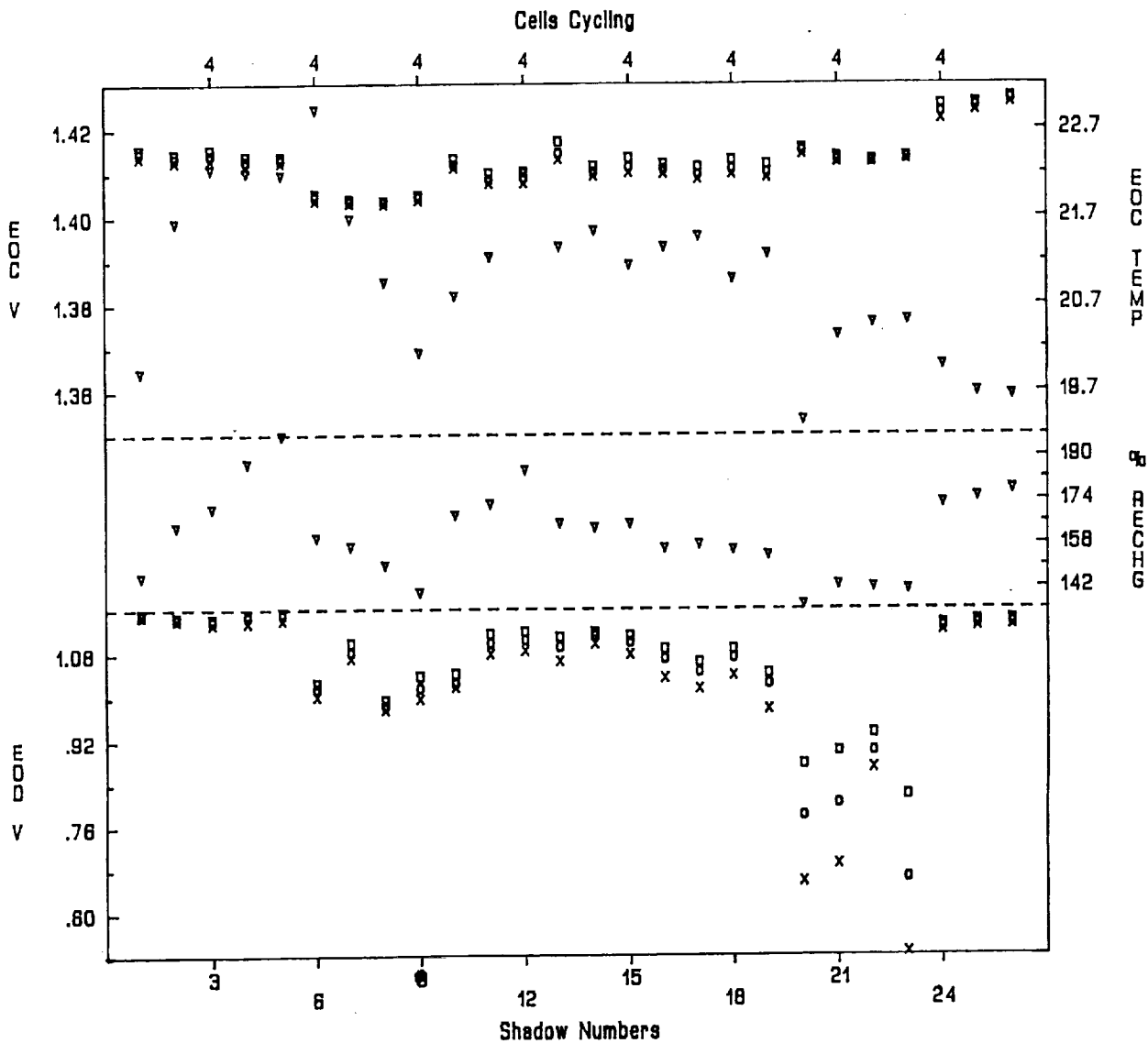


1. Shadow #1, lowered VL to 1.414 v/c, due to high per-cent recharge.
2. Shadow #1, during Cycle # 25, a system problem occurred that caused the A/Ho to be read as 21,474 A/H. The pack was then recharged with a V/L for 202 hours.
3. Shadow #3, The DOD was adjusted to 80%.
4. Cycle #218, lowered to VT4 (1.384 v/c) due to cells warming at EOC.
5. Cycle #248, raised to VT4.5 (1.404 v/c) due to low EOD volts.
6. Cycle #307, lowered to VT4 (1.394 v/c) due to warming at EOC.
7. Cycle #338, raised to VT4.5 (1.404 v/c) due to low EOD volts.
8. Cycle #408, started pack using true VT control.
9. Cycle #428, raised to VT5 (1.414 v/c) due to low EOD.
10. Shadow #21, due to chamber problems, the pack remained in OCV 28 days during Shadow Day #38.
11. Cycle #1087, raised to VT5.5 (1.424 v/c) due to low EOD.

ANNUAL TRENDPLOT  
 \*\*\*GEO\*\*\*AIR FORCE  
 TRENDF OF MID SHADOW  
 Pack: 6240S    Manf: SAFT    40.0 AH  
 Orbit: GEO    Temp (C): 20    DOD(%): 80.0

DISCHARGE (26.7 AMPS)  
 CHARGE (4.0 AMPS)  
 SHADOWS 1 THRU 28

Plot area #1 -- keys:  
 Left-side:    Right-side:  
 o -- High Cell    v -- EOC TEMP  
 o -- Average  
 x -- Low Cell  
 Plot area #2 -- keys:  
 Left-side:    Right-side:  
 OFF    v -- % RECHG  
 Plot area #3 -- keys:  
 Left-side:    Right-side:  
 o -- High Cell    OFF  
 o -- Average  
 x -- Low Cell



1. Shadow # 1, VT 5 (1.414 V/C).
2. Shadow # 4, DOD changed from 88 to 80 per cent recharge.
3. Shadow # 6, VT 4.5 (1.404 V/C) due to cells warming during charge.
4. During Shadow # 8, the pack was using a 2 step V/T. The first ten days and the last nine days of the shadow period were at VT 4.0 (1.384 V/C). During days 11 thru 33 (mid-shadow) the pack ran at VT 4.5 (1.404 V/C).
5. Shadow # 10, voltage clamp changed to voltage/temperature controlled voltage limit at VT 5 (1.414 V/C).
6. Shadow # 20, due to chamber problems, the pack remained in OCV 28 days during Shadow Day #7.
7. Shadow # 23, increased to VT 5.5 (1.414 V/C), due to low EOD.



**CONCLUSIONS OF RESULTS  
FOR SAFT CELLS**

---

**\* C/D HIGHER THAN THAT OF PRE-1986 GATES CELLS**

**\* LEO RESULTS VERIFY GENERIC QUALIFICATION OF**

**VOSA (UP TO 40 Ah) CELLS**

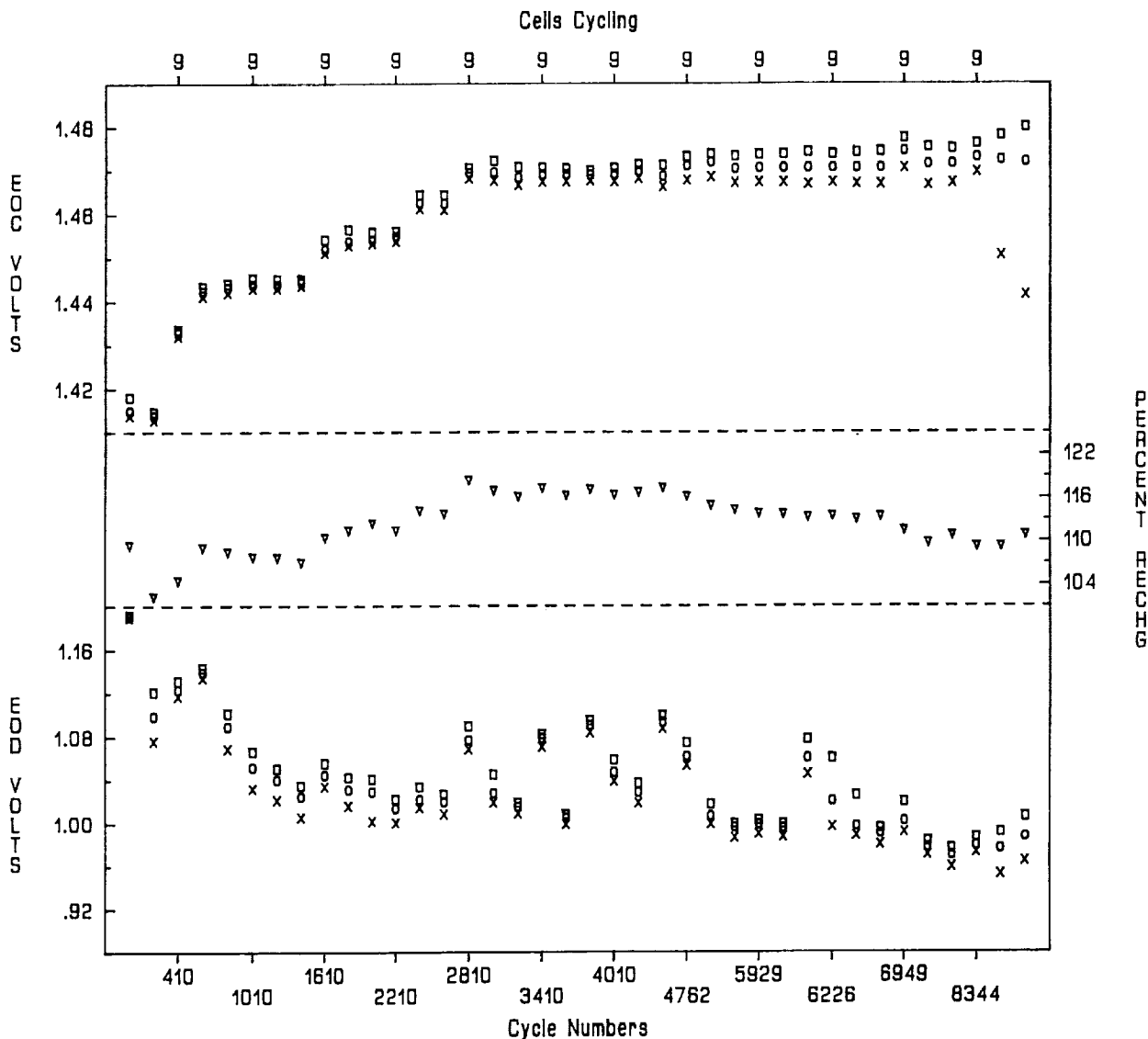
**\* RECOMMEND A NEW TERMINAL DESIGN FOR 40Ah CELLS**

ANNUAL TRENDPLOT

Pack: 6335A    Manf: GATES    35.0 AH  
 Orbit: LEO    Temp (C): 20    DOD(%): 40.0  
 Discharge(Amp/Hrs): 25.0/0.56    Charge(Amp/Hrs): 17.5/1.12

Plot area #1 -- keys:    Right-side:  
 Left-side:    OFF  
 o -- High Cell  
 o -- Average  
 x -- Low Cell  
 Plot area #2 -- keys:    Right-side:  
 Left-side:    OFF  
 v -- PERCENT RECH  
 Plot area #3 -- keys:    Right-side:  
 Left-side:    OFF  
 o -- High Cell  
 o -- Average  
 x -- Low Cell

TEST DATA AS OF OCTOBER 23, 1993



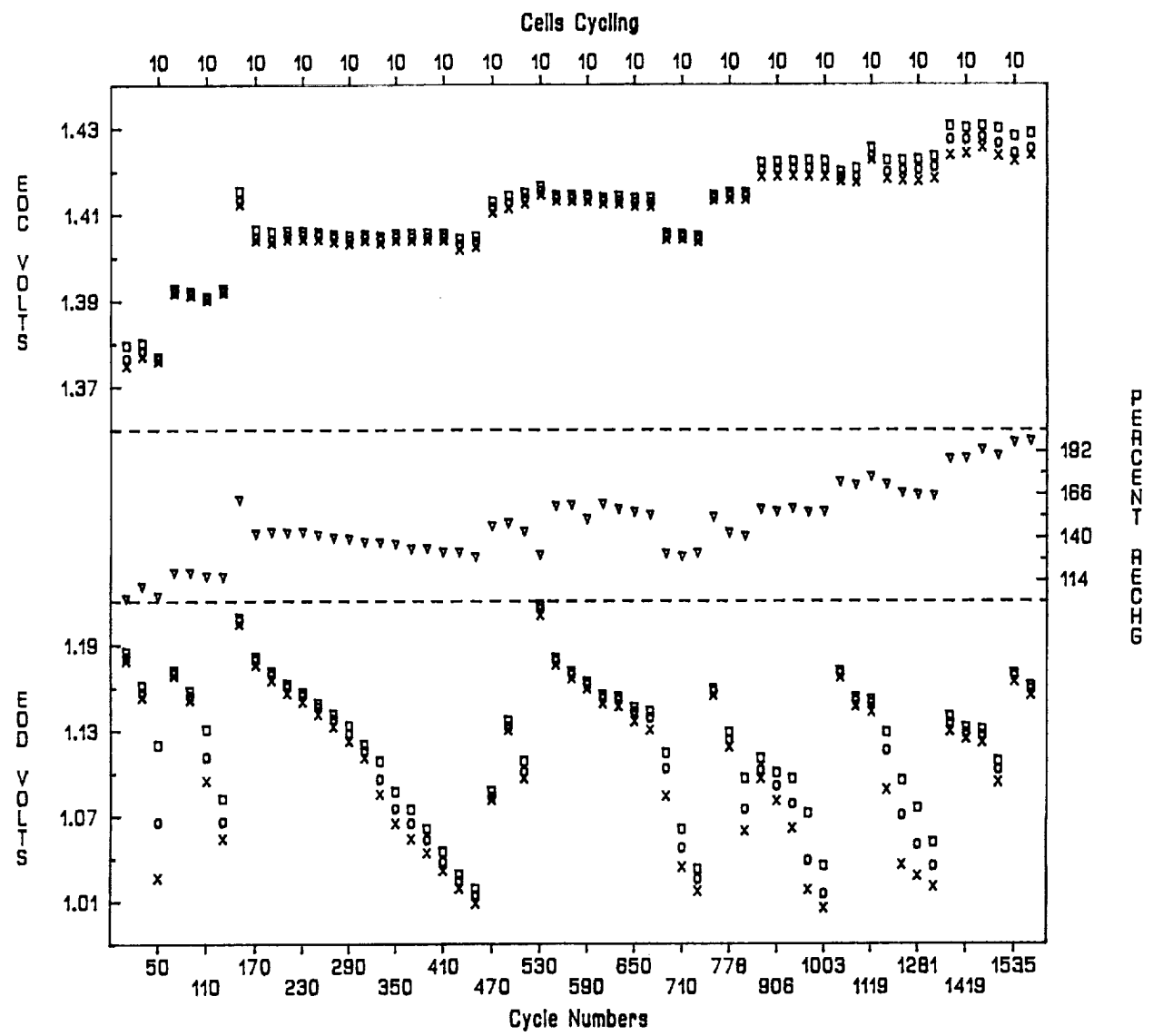
1. LIFE CYCLING STARTED AT VT 4.0 (1.380 V/C).
2. VT'S WERE INCREASED FROM 4.0 TO 8.0 IN 1/2 VT INCREMENTS DUE TO LOW EOD'S AND % RECHARGE.
3. A PERCENT OF RECHARGE INCREASE WAS NOTICED AFTER EXTENDED OPEN CIRCUIT TIMES DURING CHAMBER PROBLEMS.
4. CYCLE #3840, IT WAS NOTICED THAT ALL CELL CASES WERE SWOLLEN DUE TO HIGH PERCENT OF RECHARGE (117%).
5. CYCLE #8073, PACK SLIGHTLY RECONDITIONED WHEN TEST SYSTEM WENT DOWN. VOLTAGE STEADILY INCREASED THE NEXT 25 CYCLES AND THEN DECLINED.

ANNUAL TRENDOPLLOT

Pack: 6335B    Manf: GATES    35.0 AH  
 Orbit: GPS    Temp (C): 20    DOD(%): 41.4  
 Discharge(Amp/Hrs): 15.8/0.92    Charge(Amp/Hrs): 03.5/9.50

Plot area #1 -- keys:    Right-side:  
 Left-side:    OFF  
 □ -- High Cell  
 ○ -- Average  
 x -- Low Cell  
 Plot area #2 -- keys:    Right-side:  
 Left-side:    OFF  
 ▼ -- PERCENT RECH  
 Plot area #3 -- keys:    Right-side:  
 Left-side:    OFF  
 □ -- High Cell  
 ○ -- Average  
 x -- Low Cell

TEST DATA AS OF OCTOBER 23, 1993



1. STARTED LIFE CYCLING AT V/T 4.0(1.380 V/C).
2. VT'S WERE ADJUSTED FROM 4.0 TO 5.0, IN INCREMENTS OF 1/2 VT, DUE TO LOW EOD'S.
3. CYCLE #528, PACK WAS RECONDITIONED WITH A/HO 20.12.
4. CYCLE #694, DECREASED TO V/T 4.5(1.404 V/C) DUE TO HIGH EOD TEMP.
5. CYCLE #733, INCREASED TO V/T 5.0(1.414 V/C) DUE TO LOW EOD.
6. CYCLE #862, INCREASED TO V/T 5.5(1.424 V/C) DUE TO LOW EOD.
7. CYCLE #1005, PACK WAS RECONDITIONED WITH A/HO 19.0.
8. CYCLE #1374, INCREASED TO V/T 6.0(1.434 V/C) DUE TO LOW EOD.
9. CYCLE #1506, PACK WAS RECONDITIONED WITH A/HO 23.7.



# STRESS TEST

## 6353G

---

**TYPE**

50 A/H LIGHTWEIGHT NI-CD, GATES

**TEMPERATURE**

20 DEGREES CENTIGRADE

**ORBIT**

100 MINUTES

**DISCHARGE**

35.3 AMPS FOR 34 MINUTES, 40%DOD

**CHARGE**

25.0 AMPS WITH V/I TAPER AT V/I 6 (1.434 V/C)



# RESULTS FOR GATES CELLS

\* 35 Ah CELL, 40% DOD & 20 C: EODV > 0.987 AT 9443 CYCLES

\* 35 Ah CELL, 41.4% DOD & 20 C: EODV > 1.094 AT 1495 CYCLES  
ACCELERATED 10.4 HOUR GPS ORBIT

\* 50 Ah CELL, 40% DOD & 20 C: TESTING JUST BEGAN