Telstar 401 Reconditioning Experience

Dr. Dean W. Maurer
McKnight Associates Inc.
292 Johnston Dr.
Watchung, NJ, 07060
(908) 753-4457
or (908) 949-6690
Fax (908) 949-8082

Telstar 401 was launched December 15, 1993. It has two 58 cell 50 AH Nickel Hydrogen batteries of the Comsat design. Reconditioning is carried out with relay selected resistors across the entire battery for rates of approximately C/50 and C/100. There are individual cell voltage monitors and the discharge is carried out until the first cell reaches 0.8 volts.

Figure 1 is a composite plot to the maximum and minimum battery voltage and pressure by day since the beginning of the Spring '94 eclipse. Note that the minimum pressure is a uniform "smile" curve for each season; the minimum battery voltage is similar except for the Spring '95 season when it has become a "smirk" Note also that there is no reconditioning before the latter season. (Seen most clearly in the pressure plot). The variable depth discharges that occur between the eclipse seasons are for Arc Jet firings for station keeping.

Figures 2 & 3 are the Fall '94 and Spring '95 seasons respectively in close up. The "smirk" has been attributed to the effects of silicate poisoning for reasons beyond the scope of this talk, however, what follows is some Figures generated in ground tests at our Murray Hill laboratory on cells from the same manufacturing lot as the flight cells which show what is occurring. The silicate poisoning effect shows up most clearly in a depressed voltage in the discharge following an open circuit stand such as in the "charge retention" test.

Figure 4 shows the discharges following an open circuit stand of various duration at a temperature of -5^0 C typical of flight.

Figure 5 shows the same experiment plotted as the minimum voltage reached for the best and worst cell in the study as a function of open circuit time. Included are measurements of the internal resistance of the cells

Figure 6 shows the same type of test except that the charge time is varied keeping the open circuit and discharge the same. The worst effect is seen in the most fully charged case.

Figure 7 shows the effect of discharge temperature for the charge retention test run at $+10^0$ C. The resistive effect is seen to be very temperature dependent.

Figure 8 shows the surprising effect of the temperature of the open circuit stand period on the subsequent discharge at -5^0 C. The *warmer* the open circuit stand the worse the effect!

Figure 9 shows that a brief (3 hour) excursion to 30^0 C during an otherwise -5^0 C, 72 hour stand has a large effect on the voltage depression

Finally Figure 10 shows the effect of a prolonged trickle charge on the discharge of a -5^0 C cycle. Thus trickle charge has an effect similar to the open circuit stand.

In all cases the voltage depression is wiped out by the discharge itself and subsequent cycles will have normal appearance Therefore the data suggest that the "smirk" is a result of the prolonged trickle charge of the solstice period interspersed with the shallow (15%) discharges of the arc jets coupled with no reconditioning. Later eclipse seasons which have reconditioning are more normal but some deleterious effect is seen from the 2 to 3 week period between reconditioning and the start of the eclipse season.

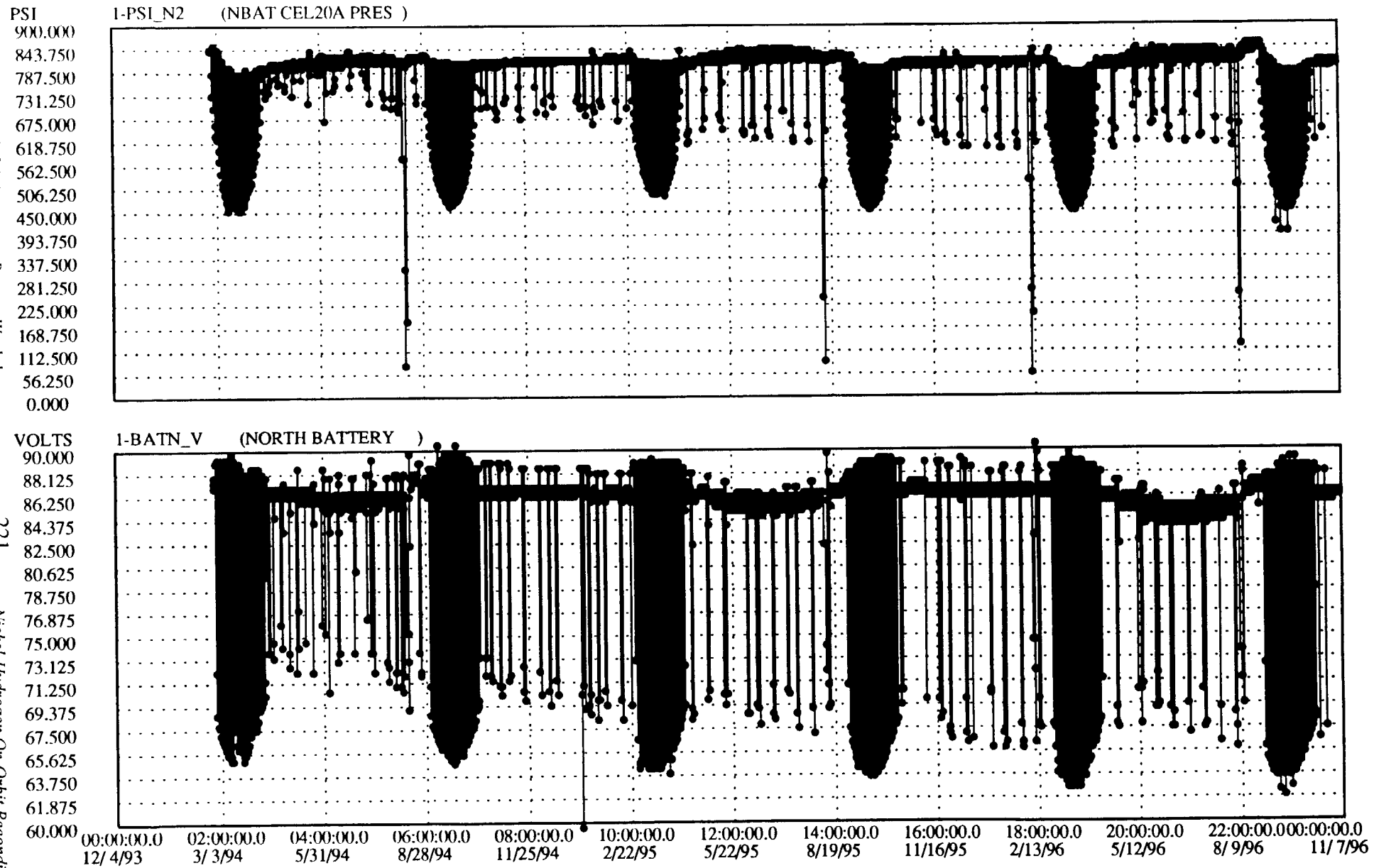

PSI
1-PSI_N2 (NBAT CEL20A PRES)
900.000
843.750
787.500
731.250
675.000
618.750
562.500
506.250
450.000
393.750
337.500
281.250
225.000
168.750
112.500
56.250
0.000
VOLTS
1-BATN_V (NORTH BATTERY)
90.000
88.125
86.250
84.375
82.500
80.625
78.750
76.875
75.000
73.125
71.250
69.375
67.500
65.625
63.750
61.875
60.000
00:00:00.0 12/ 4/93
02:00:00.0 3/ 3/94
04:00:00.0 5/31/94
06:00:00.0 8/28/94
08:00:00.0 11/25/94
10:00:00.0 2/22/95
12:00:00.0 5/22/95
14:00:00.0 8/19/95
16:00:00.0 11/16/95
18:00:00.0 2/13/96
20:00:00.0 5/12/96
22:00:00.0 8/ 9/96
00:00:00.0 11/ 7/96

Fig 1

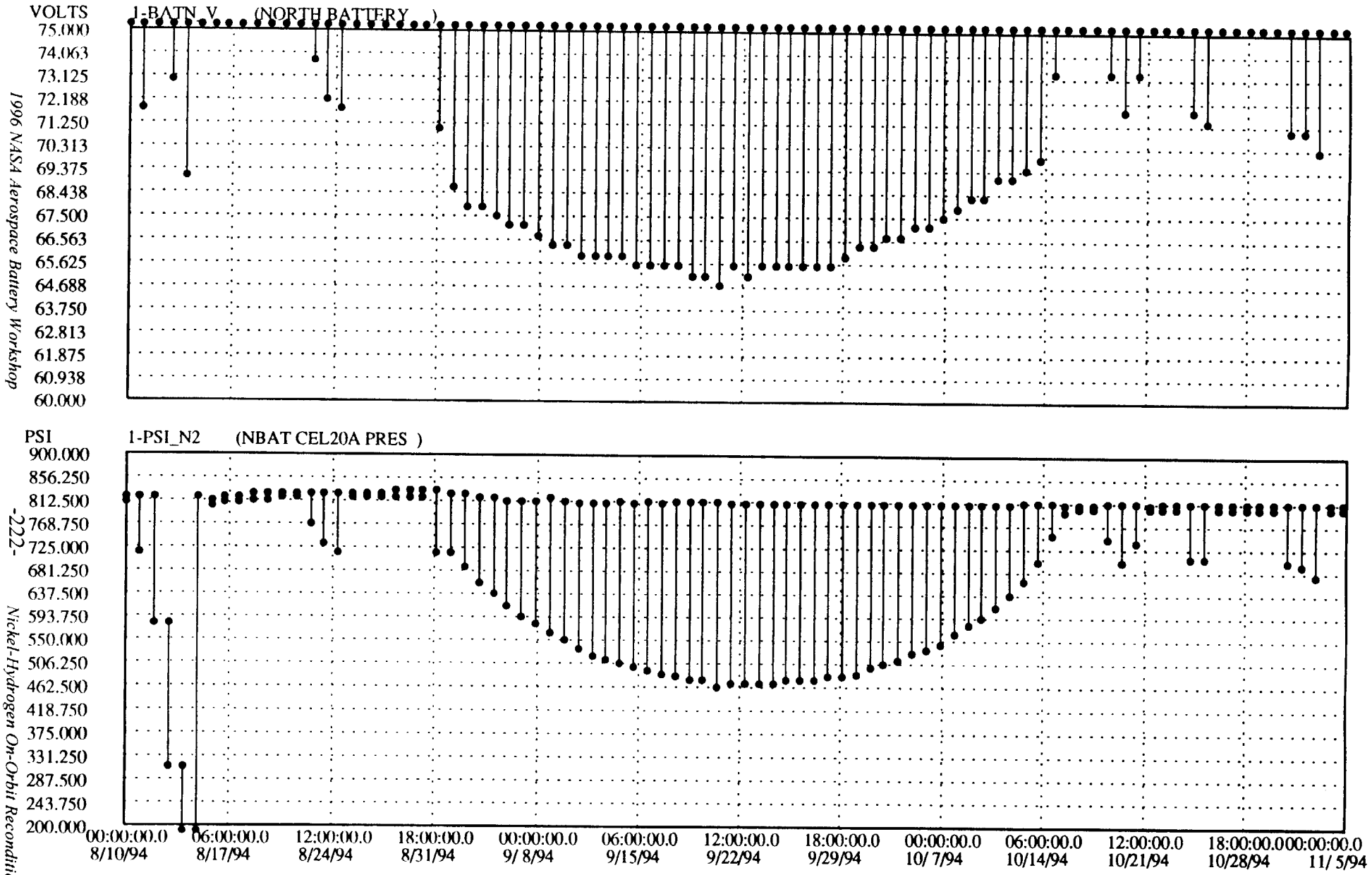

VOLTS
1-BATN_V (NORTH BATTERY)
75.000
74.063
73.125
72.188
71.250
70.313
69.375
68.438
67.500
66.563
65.625
64.688
63.750
62.813
61.875
60.938
60.000
PSI
1-PSI_N2 (NBAT CEL20A PRES)
900.000
856.250
812.500
768.750
725.000
681.250
637.500
593.750
550.000
506.250
462.500
418.750
375.000
331.250
287.500
243.750
200.000
00:00:00.0 8/10/94
06:00:00.0 8/17/94
12:00:00.0 8/24/94
18:00:00.0 8/31/94
00:00:00.0 9/ 8/94
06:00:00.0 9/15/94
12:00:00.0 9/22/94
18:00:00.0 9/29/94
00:00:00.0 10/ 7/94
06:00:00.0 10/14/94
12:00:00.0 10/21/94
18:00:00.0 10/28/94
00:00:00.0 11/ 5/94

Fig 2

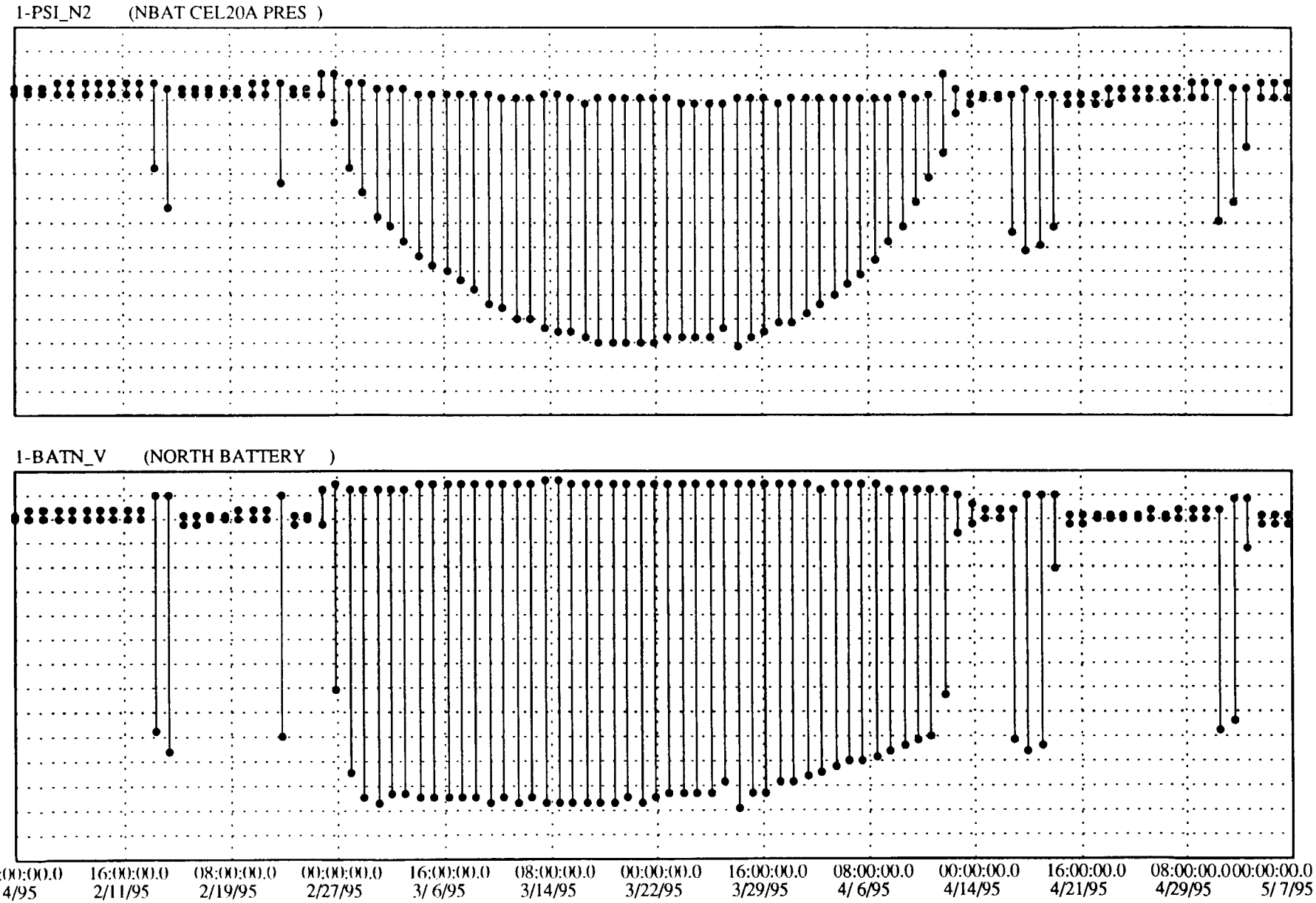

PSI
1-PSI_N2 (NBAT CEL20A PRES)
900.000
868.750
837.500
806.250
775.000
743.750
712.500
681.250
650.000
618.750
587.500
556.250
525.000
493.750
462.500
431.250
400.000
VOLTS
1-BATN_V (NORTH BATTERY)
90.000
88.125
86.250
84.375
82.500
80.625
78.750
76.875
75.000
73.125
71.250
69.375
67.500
65.625
63.750
61.875
60.000
00:00:00.0 2/ 4/95
16:00:00.0 2/11/95
08:00:00.0 2/19/95
00:00:00.0 2/27/95
16:00:00.0 3/ 6/95
08:00:00.0 3/14/95
00:00:00.0 3/22/95
16:00:00.0 3/29/95
08:00:00.0 4/ 6/95
00:00:00.0 4/14/95
16:00:00.0 4/21/95
08:00:00.0 4/29/95
00:00:00.0 5/ 7/95

Fig 3

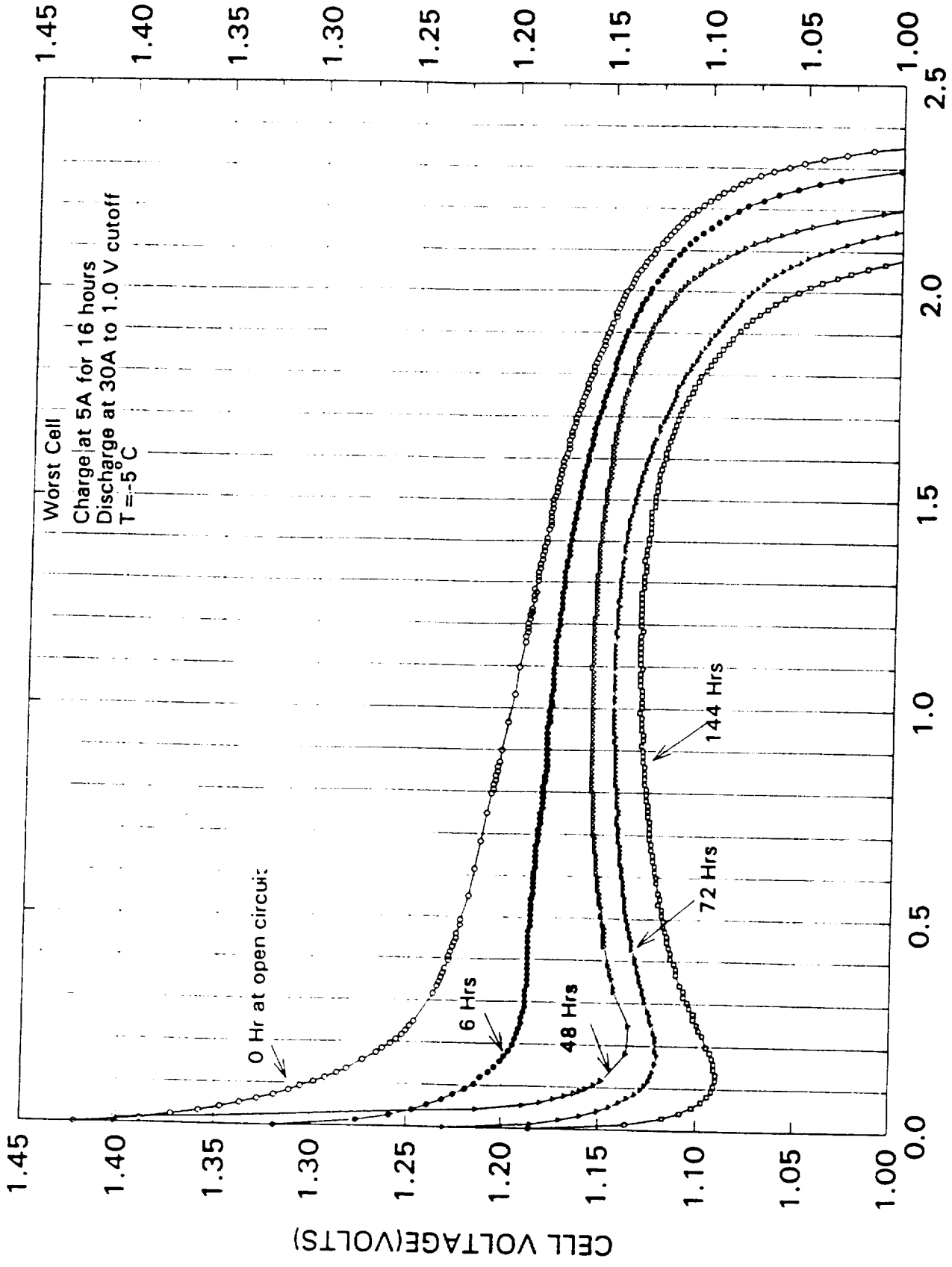

Worst Cell
Charge at 5A for 16 hours
Discharge at 30A to 1.0 V cutoff
T=-5°C
0 Hr at open circuit
6 Hrs
48 Hrs
72 Hrs
144 Hrs
CELL VOLTAGE(VOLTS)
TIME(HOURS)
1.45
1.40
1.35
1.30
1.25
1.20
1.15
1.10
1.05
1.00
0.0
0.5
1.0
1.5
2.0
2.5

Fig 4

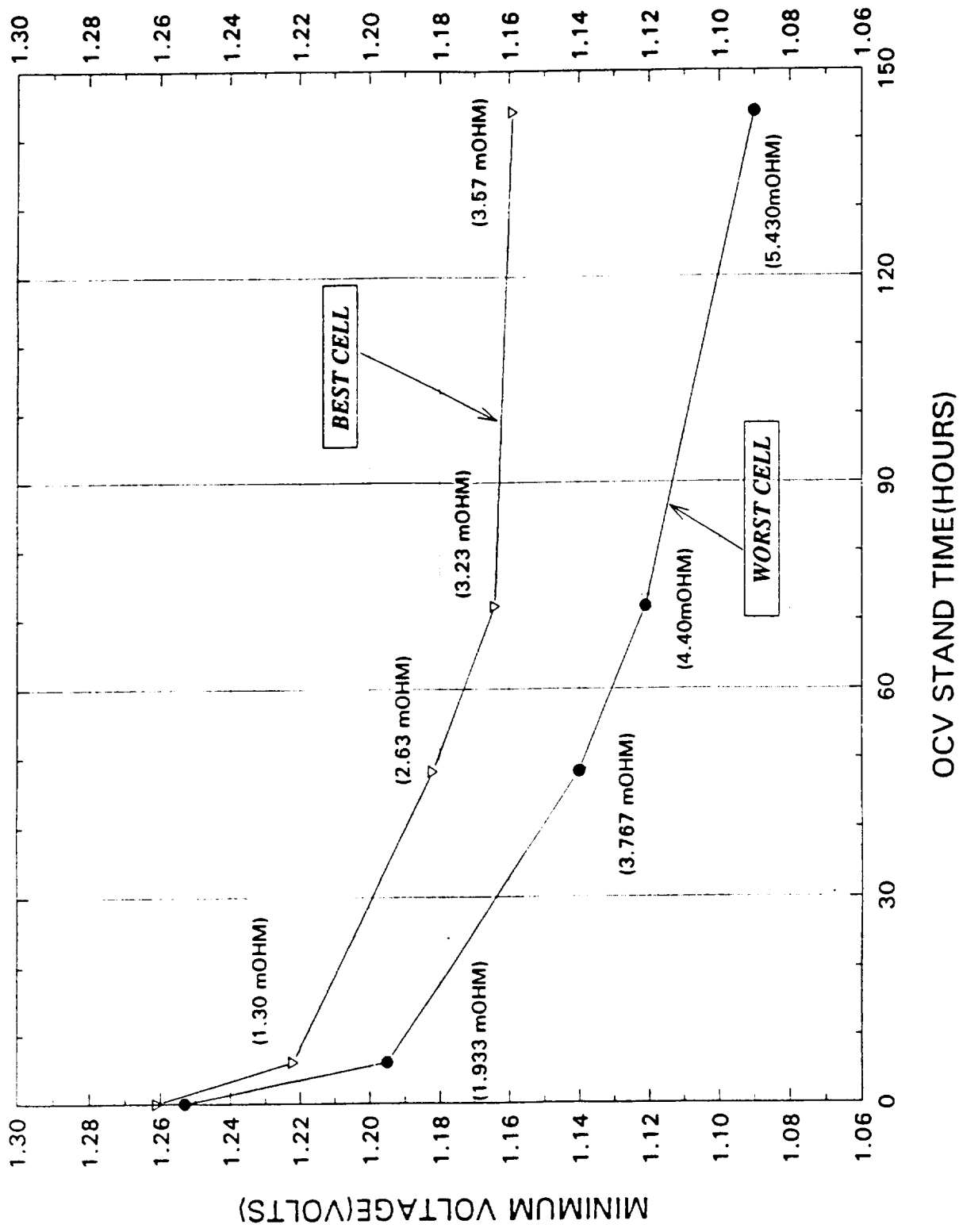
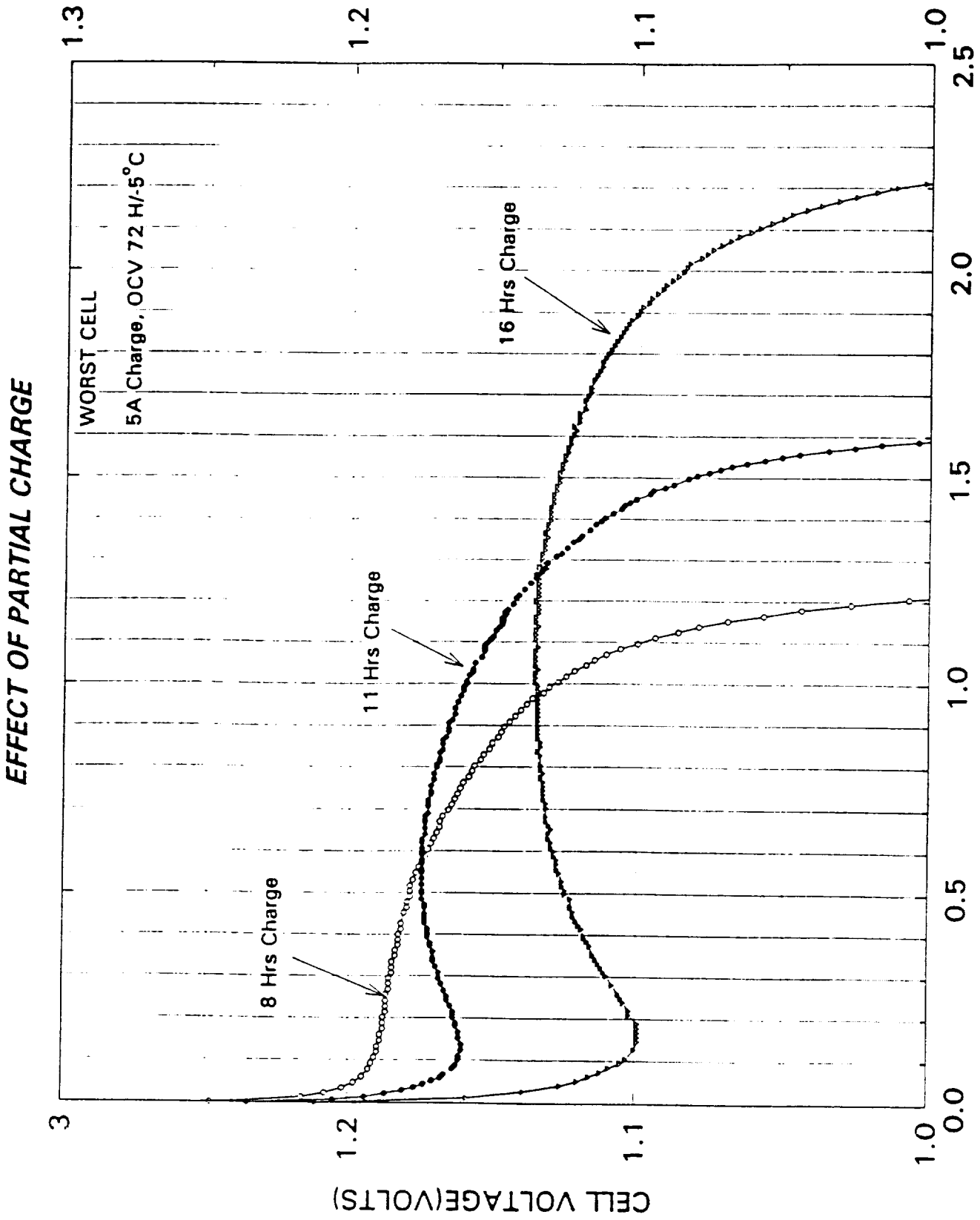

MINIMUM VOLTAGE(VOLTS)
OCV STAND TIME(HOURS)
BEST CELL
WORST CELL
(1.30 mOHM)
(2.63 mOHM)
(3.23 mOHM)
(3.57 mOHM)
(1.933 mOHM)
(3.767 mOHM)
(4.40mOHM)
(5.430mOHM)
1.30
1.28
1.26
1.24
1.22
1.20
1.18
1.16
1.14
1.12
1.10
1.08
1.06
0
30
60
90
120
150

Fig 5


EFFECT OF PARTIAL CHARGE
WORST CELL
5A Charge, OCV 72 H/-5°C
8 Hrs Charge
11 Hrs Charge
16 Hrs Charge
CELL VOLTAGE(VOLTS)
TIME(HOURS)
1.3
1.2
1.1
1.0
2.5
2.0
1.5
1.0
0.5
0.0
3
1.2
1.1
1.0

F-196

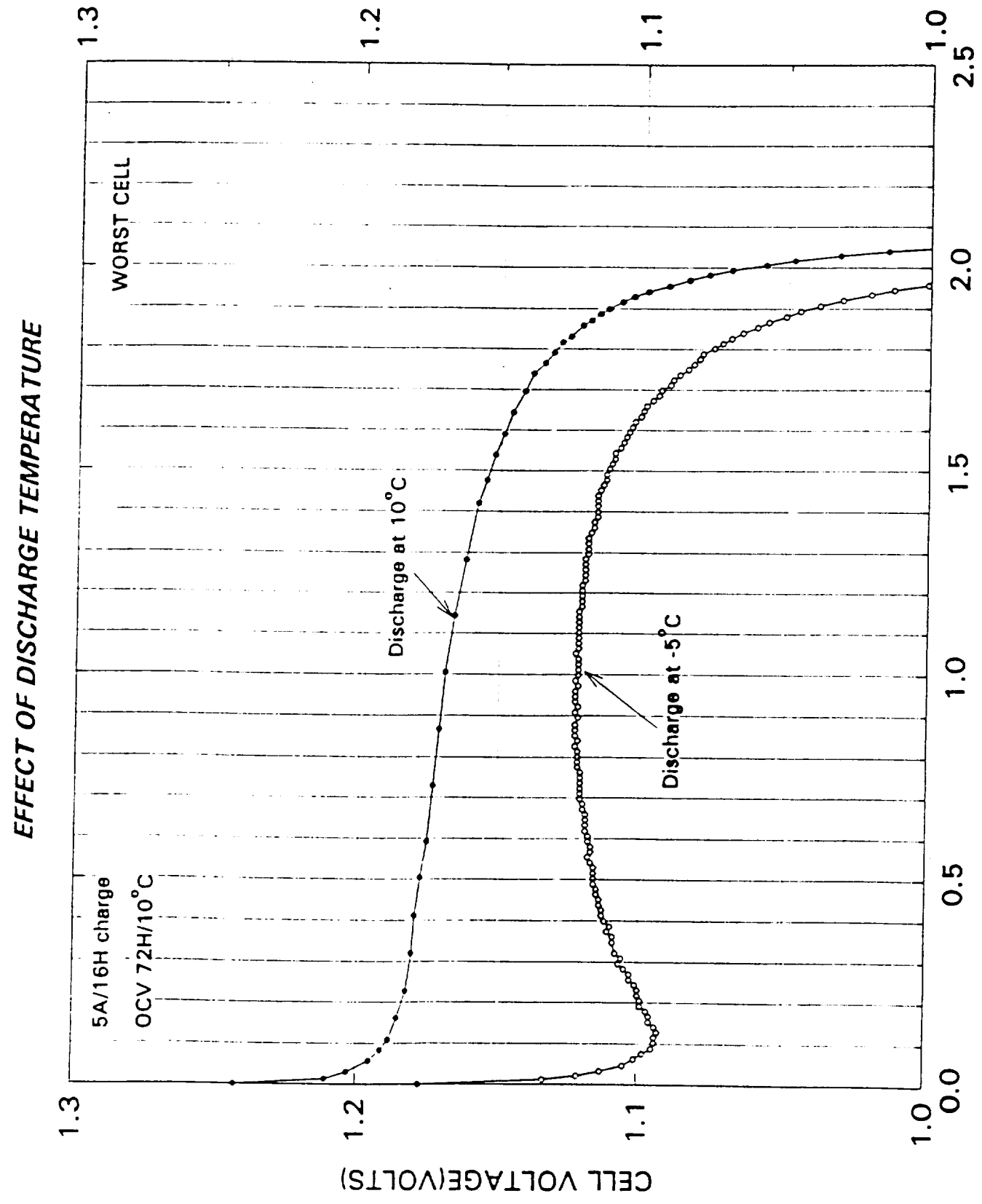

EFFECT OF DISCHARGE TEMPERATURE
WORST CELL
5A/16H charge
OCV 72H/10°C
Discharge at 10°C
Discharge at -5°C
CELL VOLTAGE(VOLTS)
TIME(HOURS)
1.3
1.2
1.1
1.0
0.0
0.5
1.0
1.5
2.0
2.5

Fig 7

OCV STAND FOR 72 HOURS AT DIFFERENT TEMPERATURES

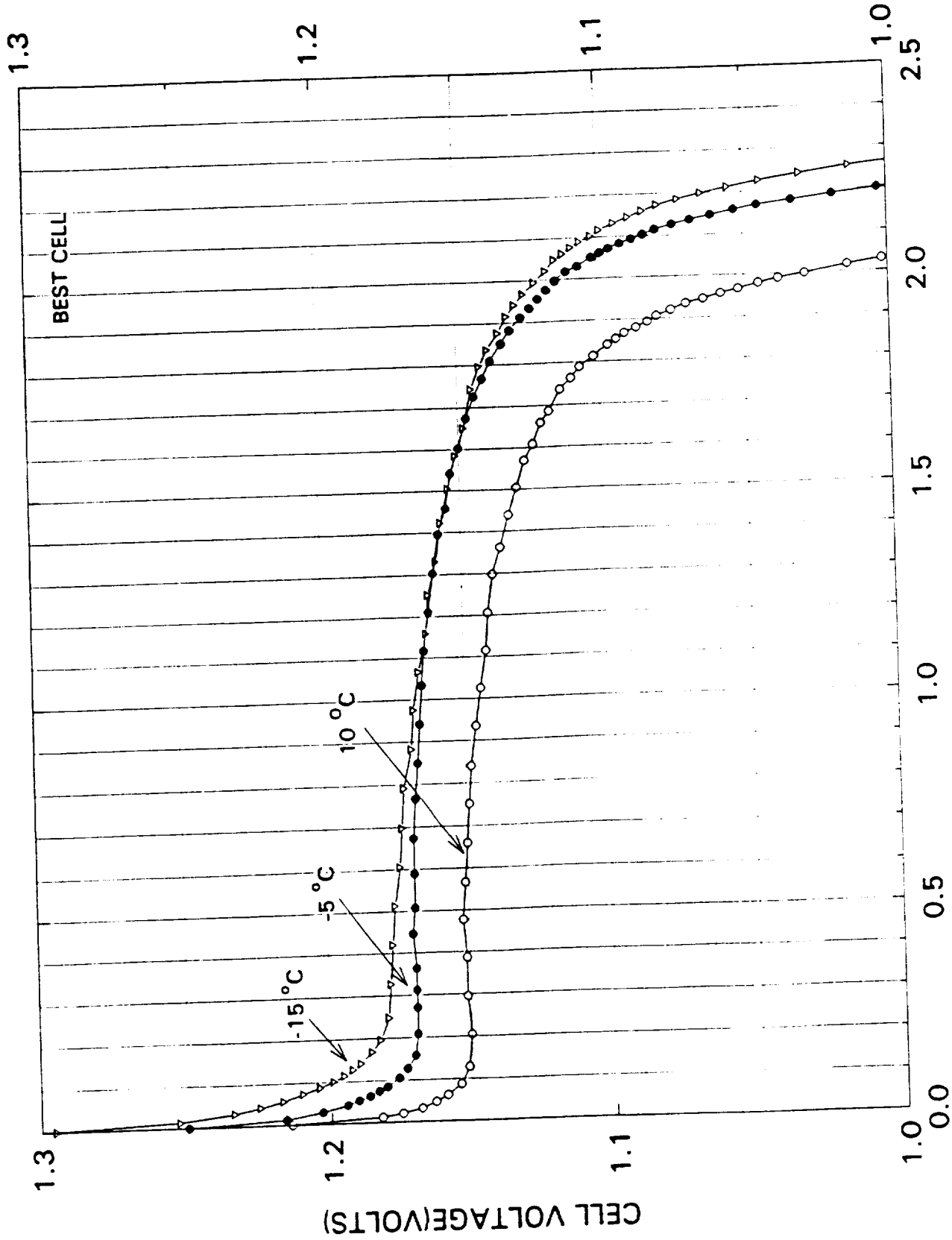


Fig 8

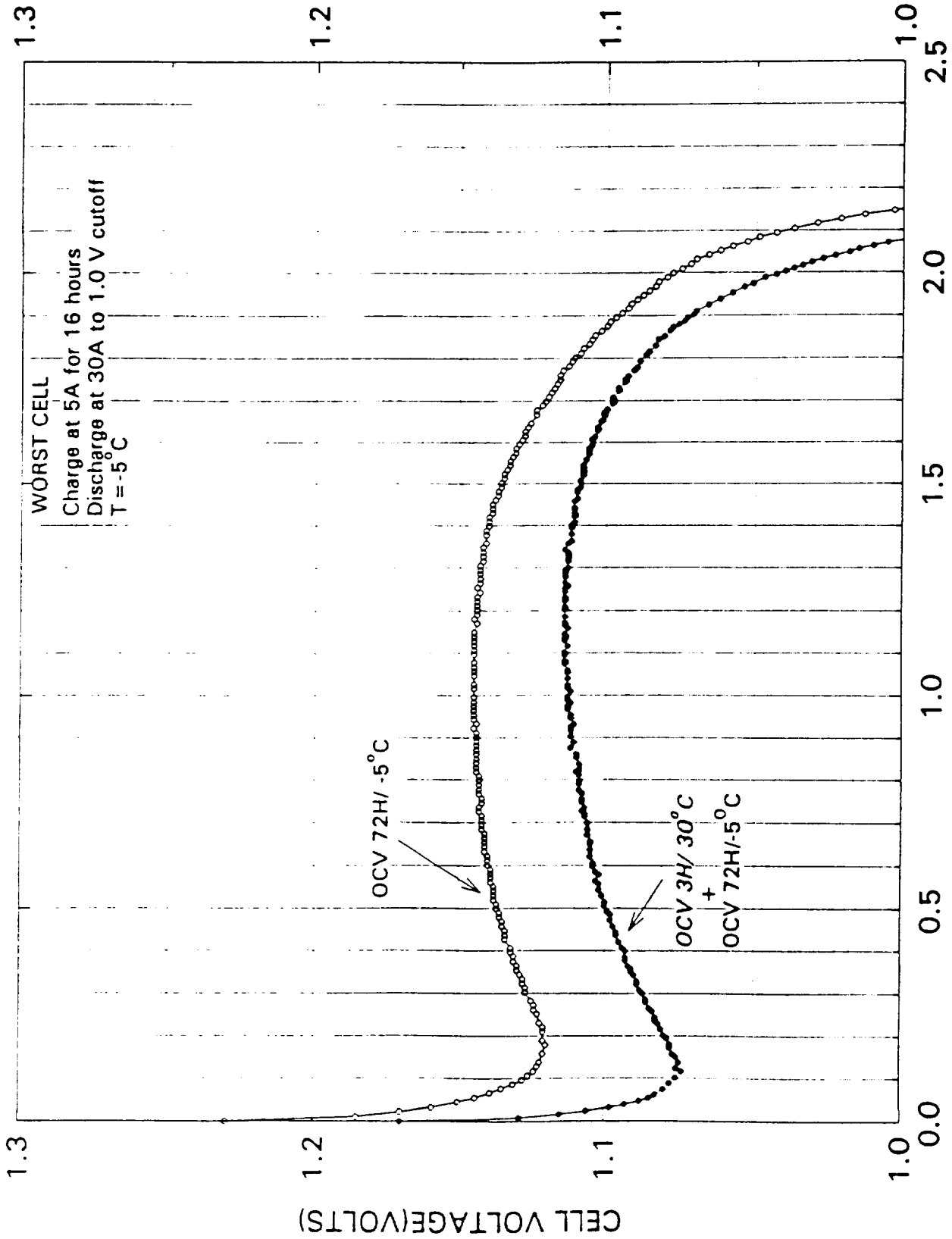

WORST CELL
Charge at 5A for 16 hours
Discharge at 30A to 1.0 V cutoff
T = -5°C
OCV 72H/ -5°C
OCV 3H/ 30°C
+
OCV 72H/-5°C
CELL VOLTAGE(VOLTS)
TIME(HOURS)
1.3
1.2
1.1
1.0
0.0
0.5
1.0
1.5
2.0
2.5

Fig 9

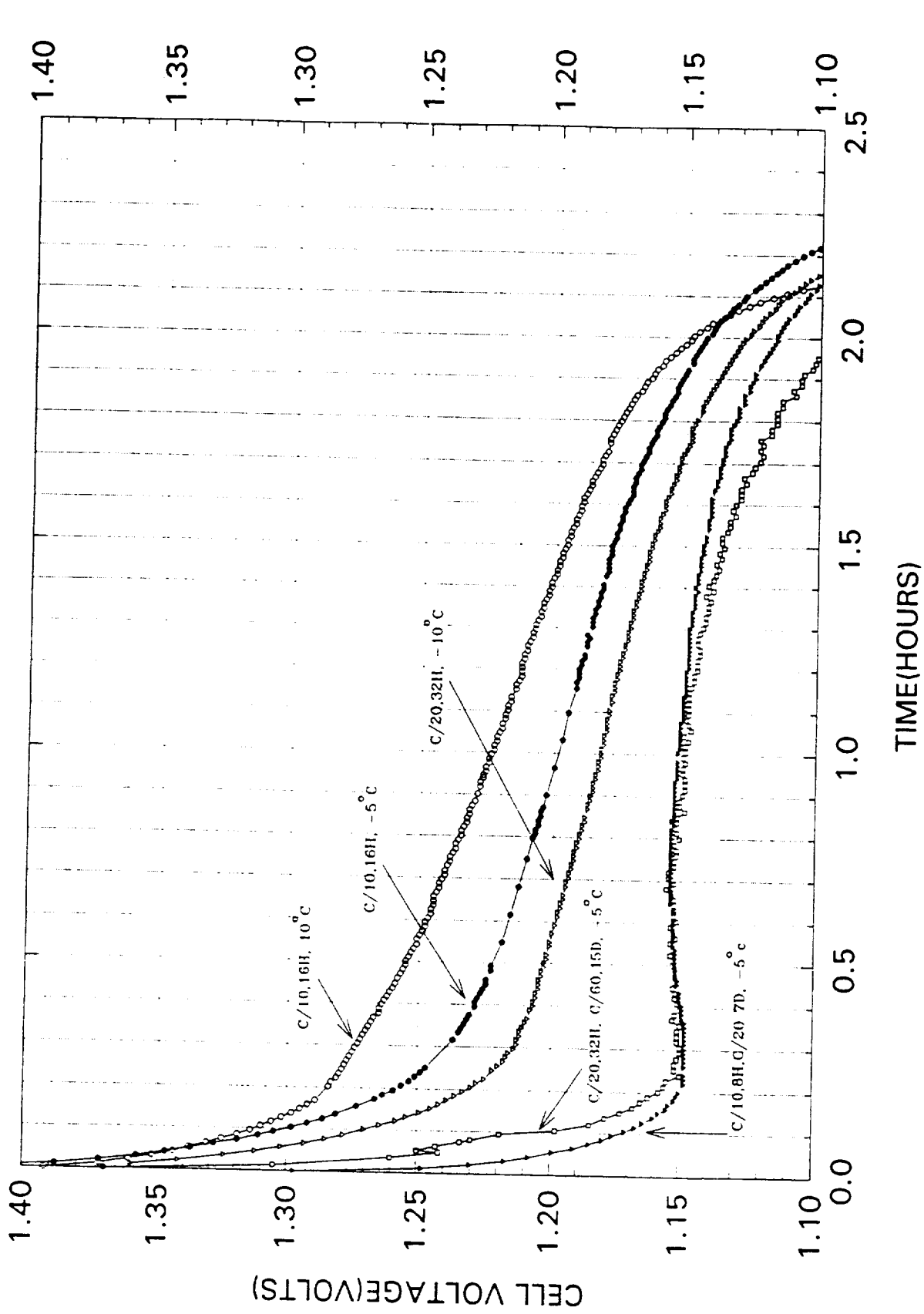

CELL #3
CELL VOLTAGE(VOLTS)
TIME(HOURS)
1.40
1.35
1.30
1.25
1.20
1.15
1.10
0.0
0.5
1.0
1.5
2.0
2.5
C/10,16H, 10°C
C/10,16H, -5°C
C/20,32H, -10°C
C/20,32H, C/60,15D, +5°C
C/10,8H,C/20 7D, -5°C

Fig 10