Design and Performance Data For 81 Ah FNC Cells

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Background
Rocketdyne FNC Activity

- Rocketdyne contracted with Acme Aerospace in early 1994 to develop and test an 81 Ah FNC cell as a lower cost alternative to Ni-H2 cells currently targeted for the International Space Station

- Acme designed, developed, tested and initiated LEO cycle testing 8 months from receipt of contract award

- Rocketdyne has accumulated 2 years of LEO cycle test data under several accelerated test regimes

- This presentation is the first public release of Rockedyne/Acme 81 Ah FNC cell performance and cycle life data

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Background
FNC Technology

- Acme Aerospace started production of FNC cells in 1992 under license from Daug-Hoppecke in West Germany
- Several OEM contracts were secured utilizing FNC sealed cells for military and commercial aircraft
- Acme slightly modified several 7 Ah aircraft quality cells and began testing at JPL in 1992. These cells achieved 9500 LEO cycles at 40% DOD at 20 ° C
- Limited design changes were made in '93-'94 and were implemented in several battery packs subsequently put on LEO tests in '94-'95 both at Acme and at customer's laboratories.
- The Rocketdyne test is the most extensive accelerated LEO testing on FNC cells to date

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FNC Cell
Design Features

Positive Plaque	Nickel plated polyolefin fibers
Positive Impregnation	Mechanical loading @ room temperature, neutral pH, no Nitrates
Negative Plaque	Nickel plated polyolefin fibers
Negative Impregnation	Mechanical loading @ room temperature, neutral pH, and no Nitrates
Separator	Polypropylene permanently wetable Pore size less than 5 micron
Electrolyte	30% KOH
Terminals	Nickel
Terminal Seals	Ziegler Crimp Seal
Case	Welded stainless steel, hermetically sealed

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X81 Design Parameters

Theoretical Positive Capacity	96 Ah +/- 3
Theoretical Negative Capacity	275 Ah +/- 6
Theoretical Neg/Pos Ratio	2.85 +/- 0.15
Active Neg/Pos Ratio	2.1 +/- 0.1
Positive Electrode Loading	1.5 g/cc void
Seperator Thickness	12 mil
Electrolyte Volume	4.1 +/- 0.1 ml/design Ah
Weight	2860 g +/- 30 g
Mid-Design Energy Density	40 Wh/kg
Internal Impeadance @ 1 sec, 24° C	0.46 mohm

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ATP DATA

Cell Number	Ref. Capacity C/2 Ah	Impeadance 1 Sec mohm	LEO Profile
* 6	81.0	0.54	27°C Accelerated
7	85.2	0.52	"
8	84.9	0.54	"
9	85.2	0.54	-10°C Accelerated
10	84.3	0.51	"
11	84.6	0.51	"
12	85.2	0.54	10°C @ 60% DOD
13	84.7	0.54	"
14	85.2	0.54	"
* 22	89.9		10°C Accelerated
15	84.5	0.53	"
16	85.8	0.54	"
17	84.5	0.52	"
18	84.2	0.51	10°C Nominal
19	84.9	0.53	"
20	84.1	0.54	"
* 1	90.5	0.58	"
* 2	91.0	0.52	"
Average all:	86 +/- 5	0.54 +/- 0.04	
* Avg (excluding 1,2,6,22)	85 +/- 1	0.53 +/- 0.02	

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Test Matrix

Pack Number	Number of Cells	Test Temp	DOD	Disch. Rate	Cycles/ Day	Number of Cycles as of 22 Nov 96
1	3	27° C	35%	97 Amps	30	9,500
2	3	-10° C	35%	97 Amps	30	13,800
3	4	10° C	35%	97 Amps	30	15,800
4	5	10° C	35%	49 Amps	16	7,900
5	3	10° C	60%	83 Amps	16	7,780

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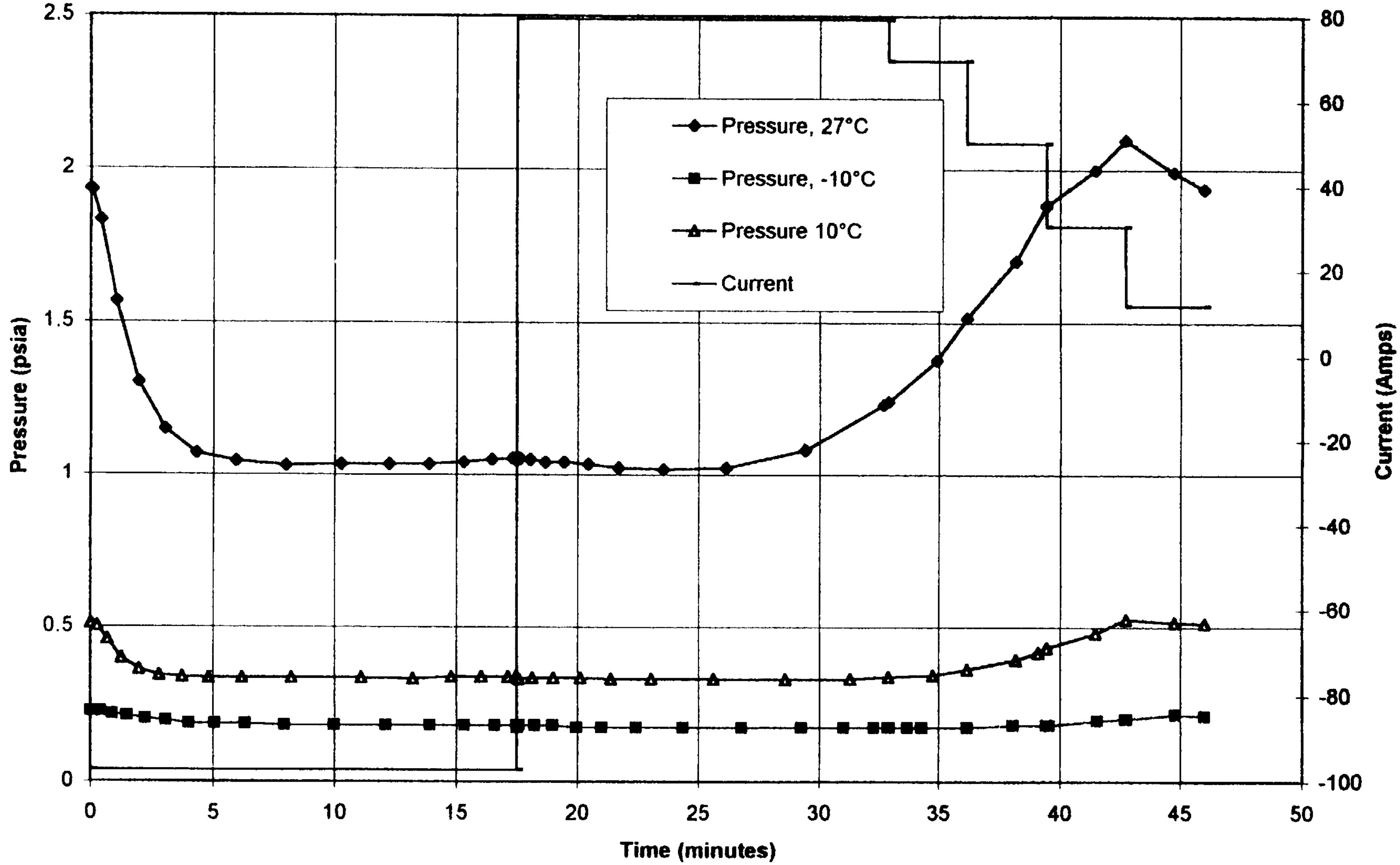
35% DoD Accelerated LEO
Current and Internal Pressure



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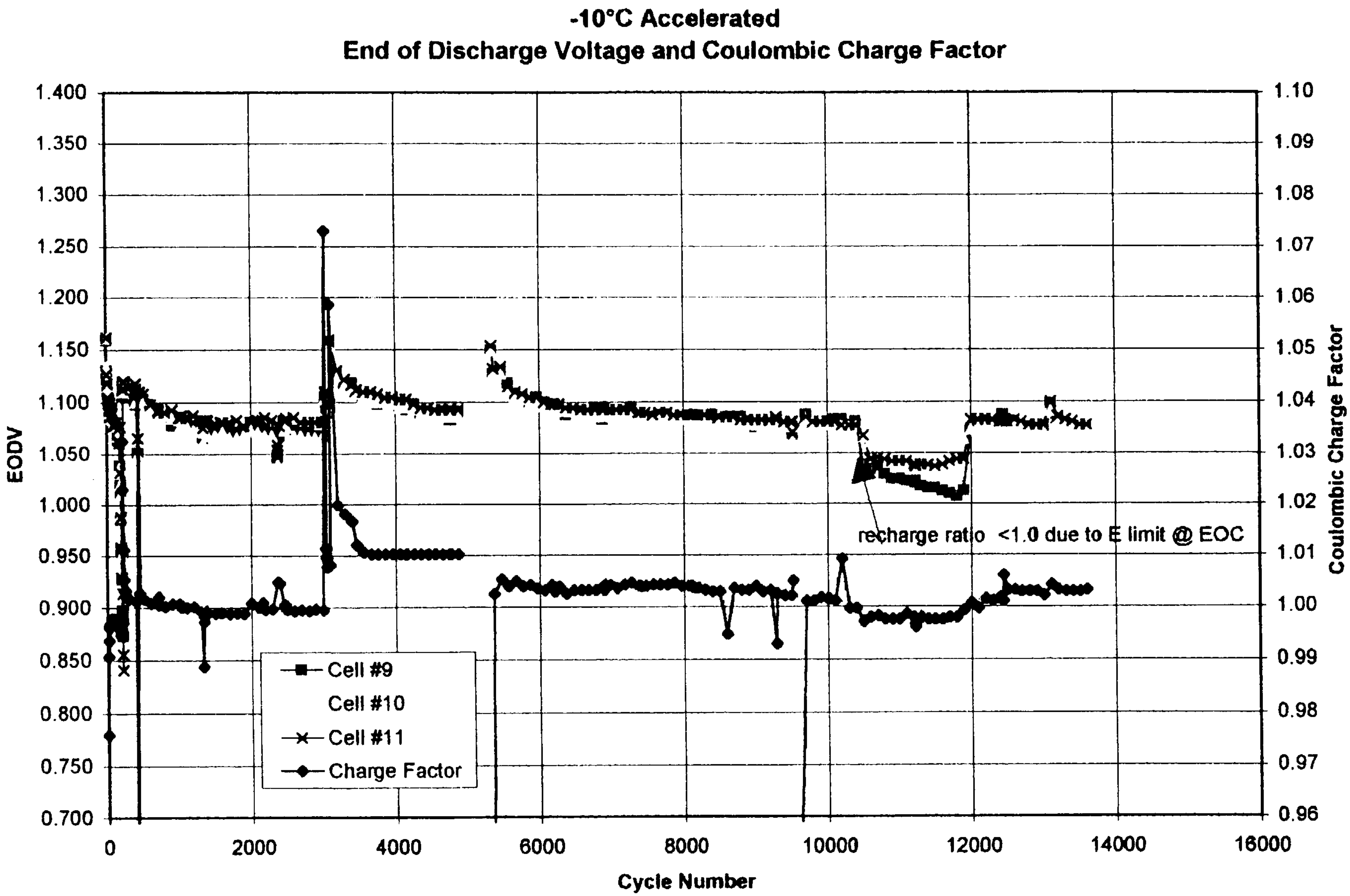

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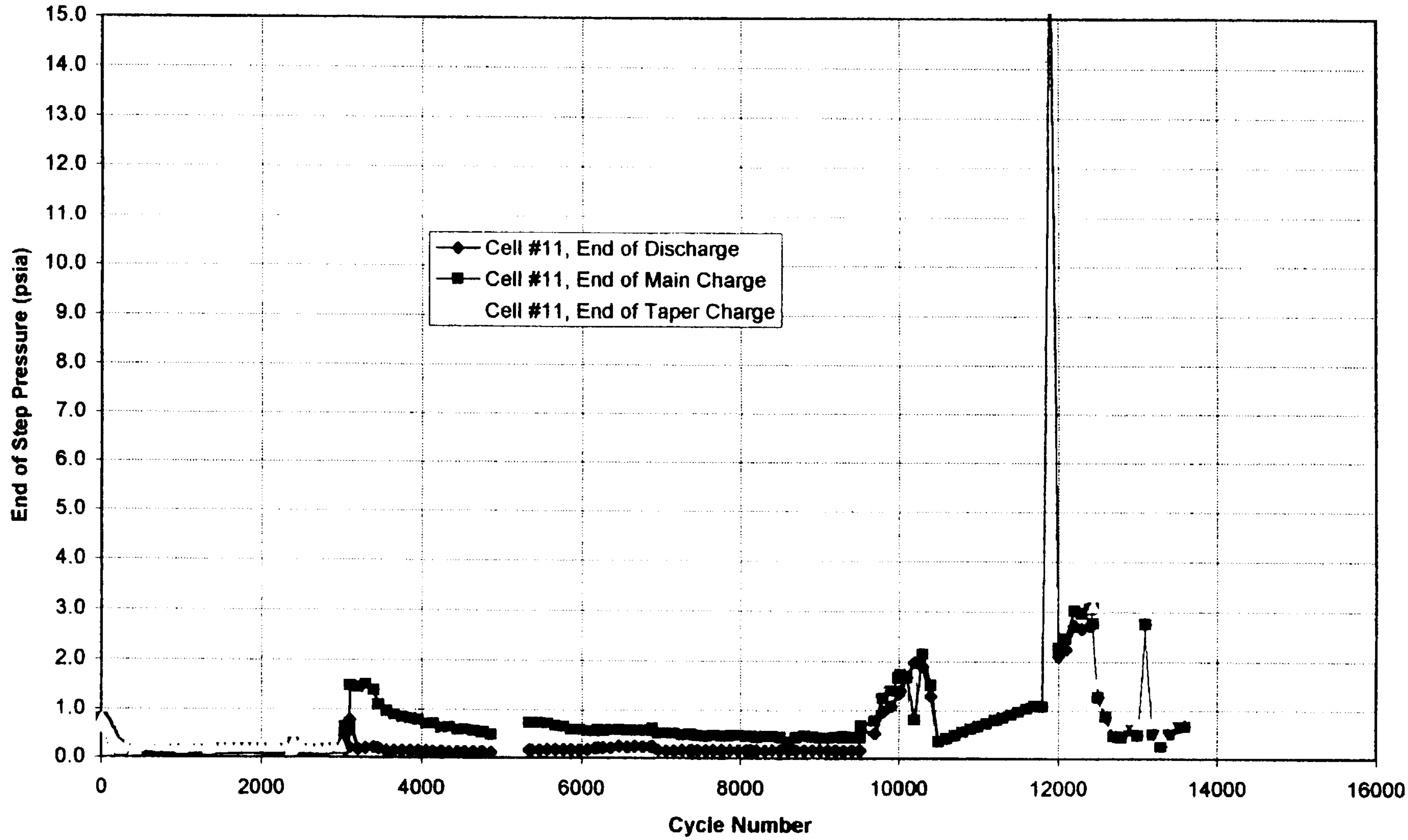
-10°C Accelerated
Internal Pressure



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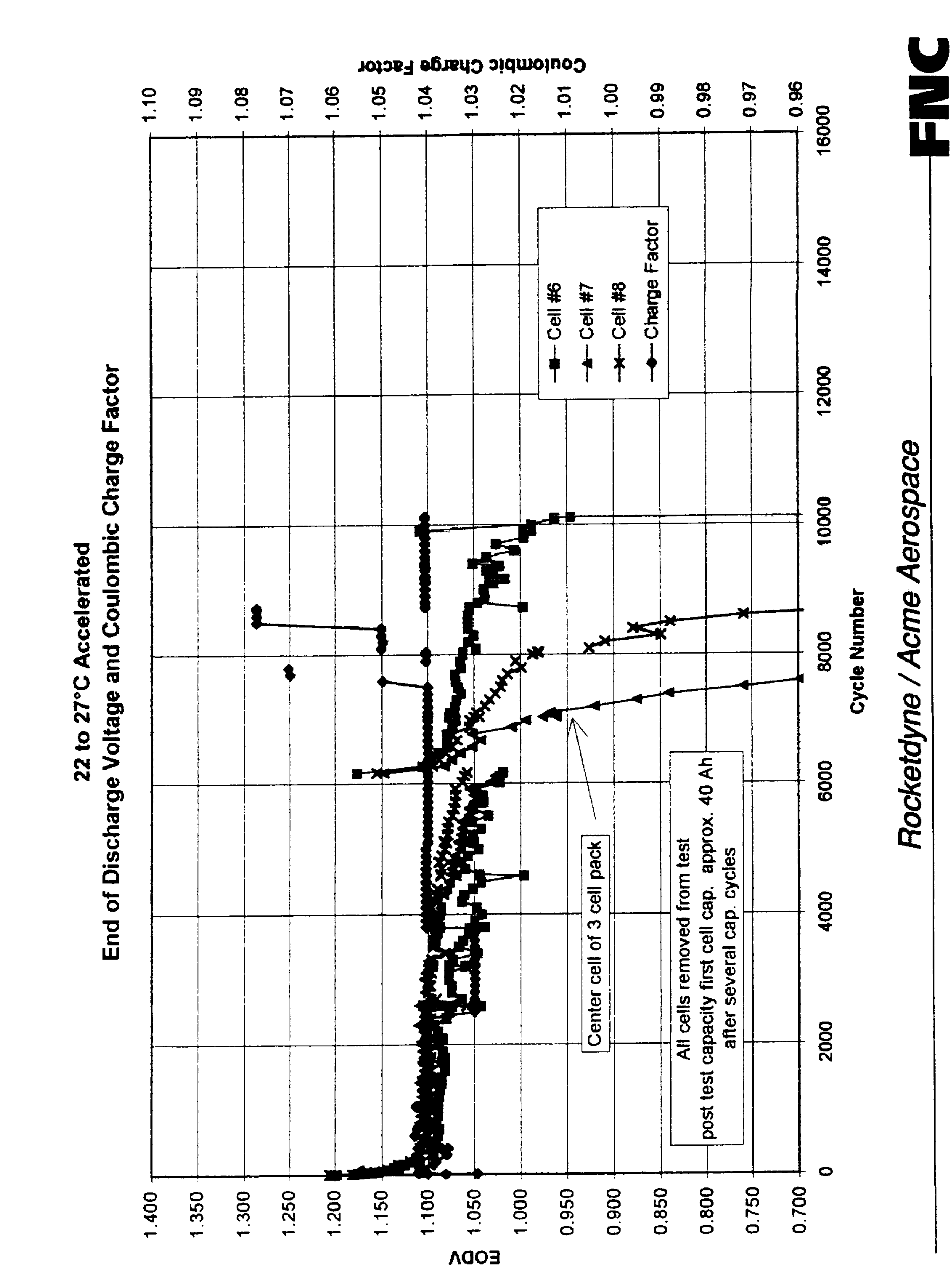
22 to 27°C Accelerated
End of Discharge Voltage and Coulombic Charge Factor
EODV
Coulombic Charge Factor
Cycle Number
Cell #6
Cell #7
Cell #8
Charge Factor
Center cell of 3 cell pack
All cells removed from test
post test capacity first cell cap. approx. 40 Ah
after several cap. cycles
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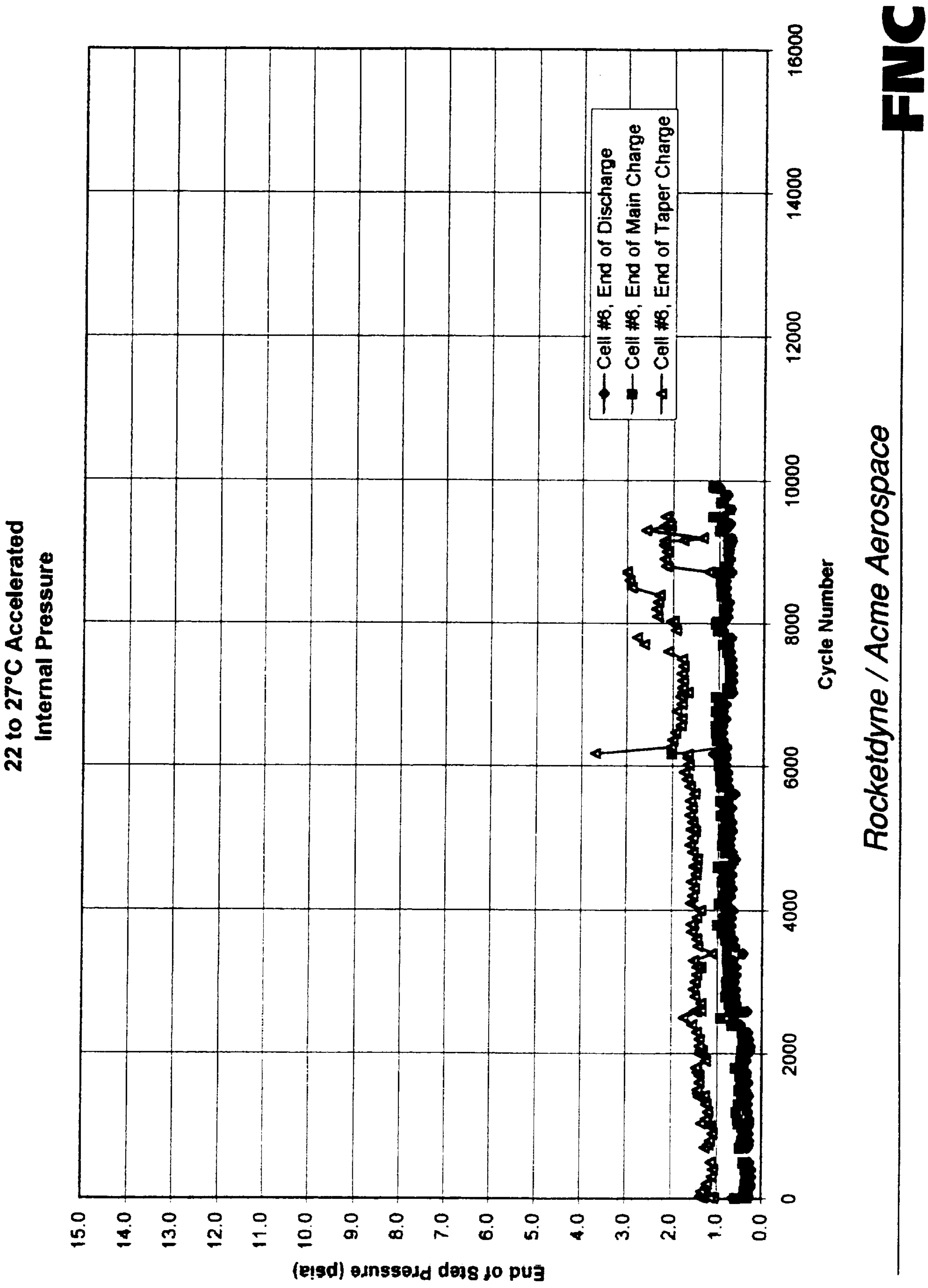
22 to 27°C Accelerated
Internal Pressure
End of Step Pressure (psia)
15.0
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0
2000
4000
6000
8000
10000
12000
14000
16000
Cycle Number
Cell #6, End of Discharge
Cell #6, End of Main Charge
Cell #6, End of Taper Charge
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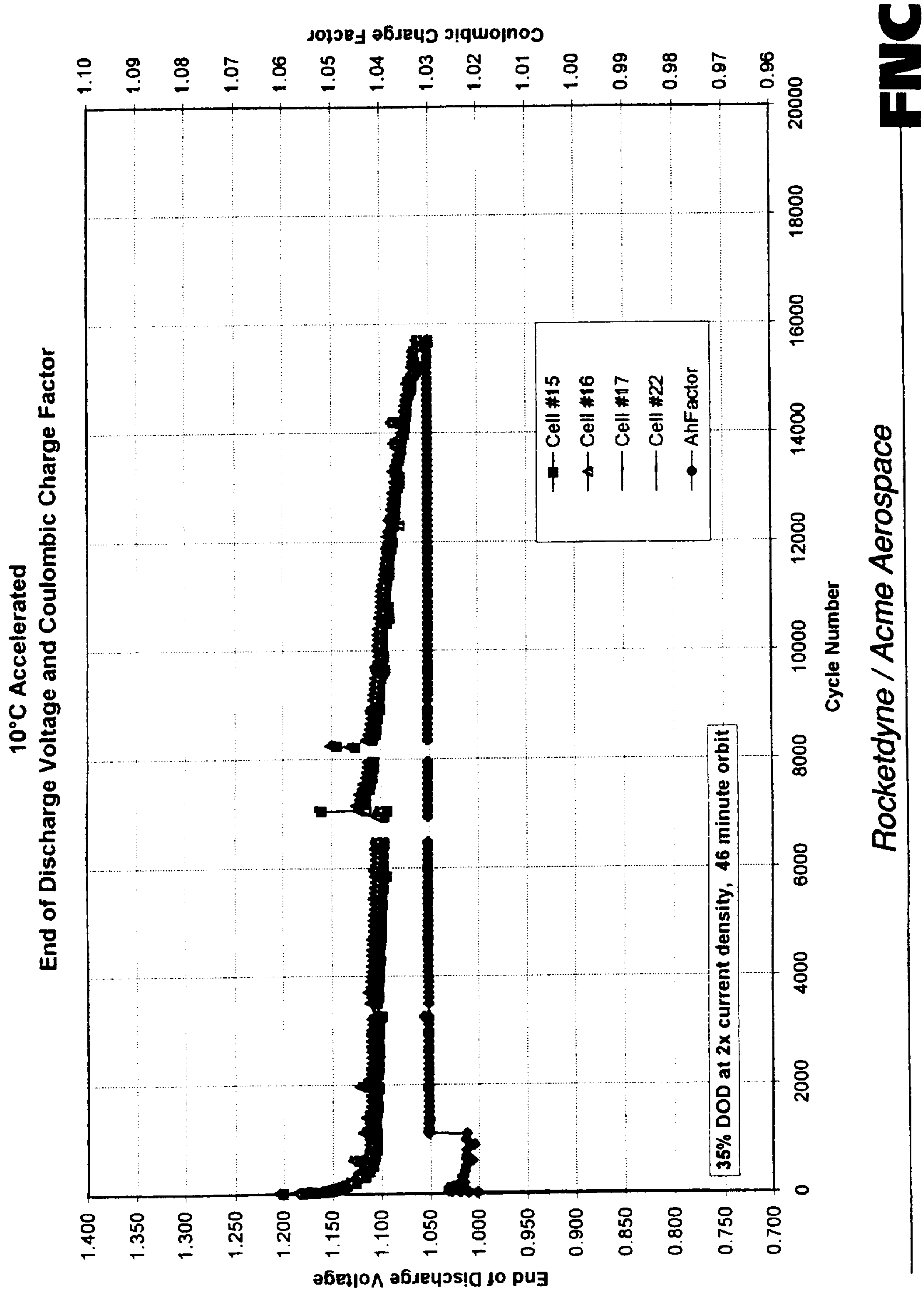
10°C Accelerated
End of Discharge Voltage and Coulombic Charge Factor
End of Discharge Voltage
1.400
1.350
1.300
1.250
1.200
1.150
1.100
1.050
1.000
0.950
0.900
0.850
0.800
0.750
0.700
Coulombic Charge Factor
1.10
1.09
1.08
1.07
1.06
1.05
1.04
1.03
1.02
1.01
1.00
0.99
0.98
0.97
0.96
Cycle Number
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
Cell #15
Cell #16
Cell #17
Cell #22
AhFactor
35% DOD at 2x current density, 46 minute orbit
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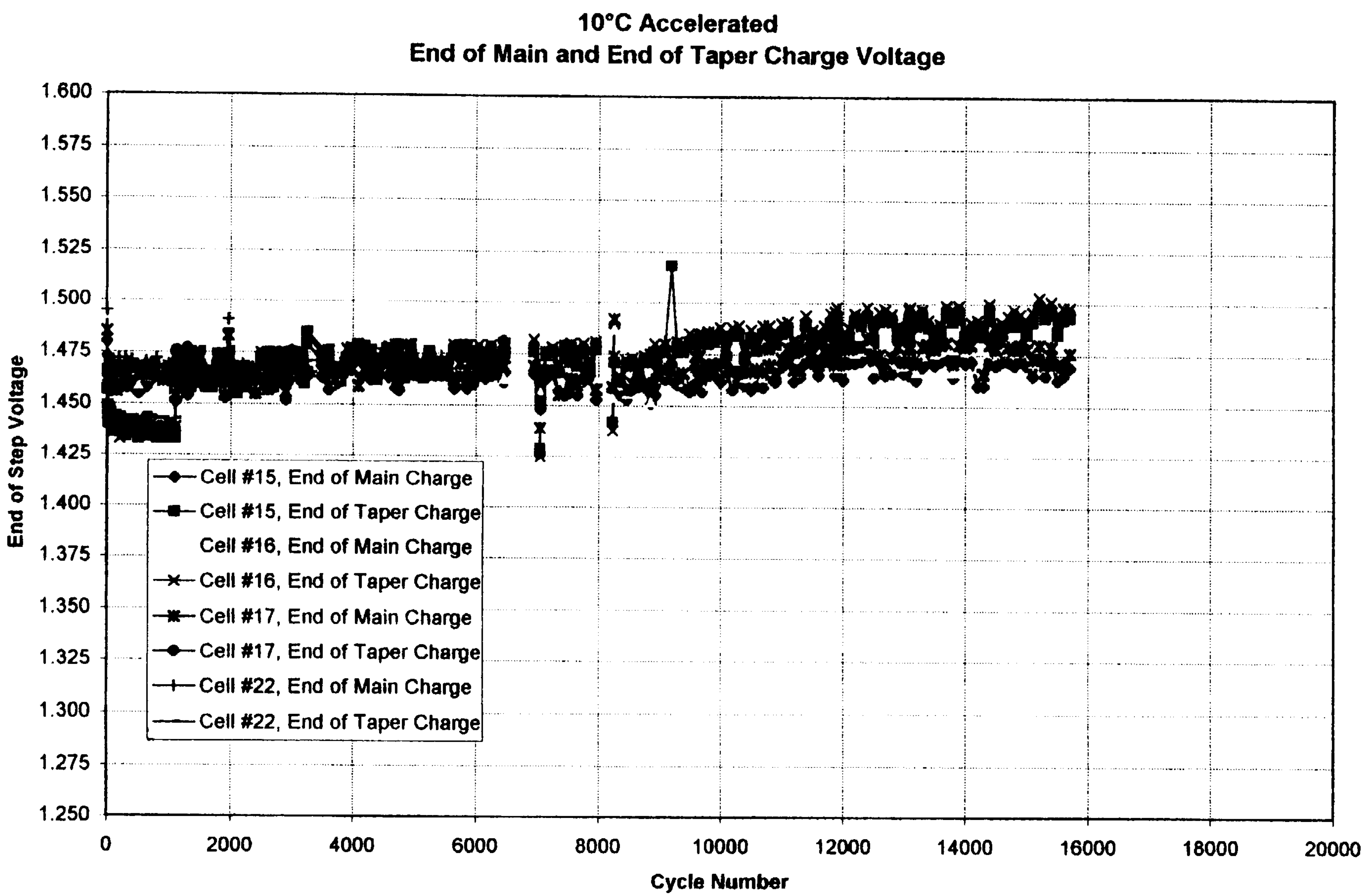

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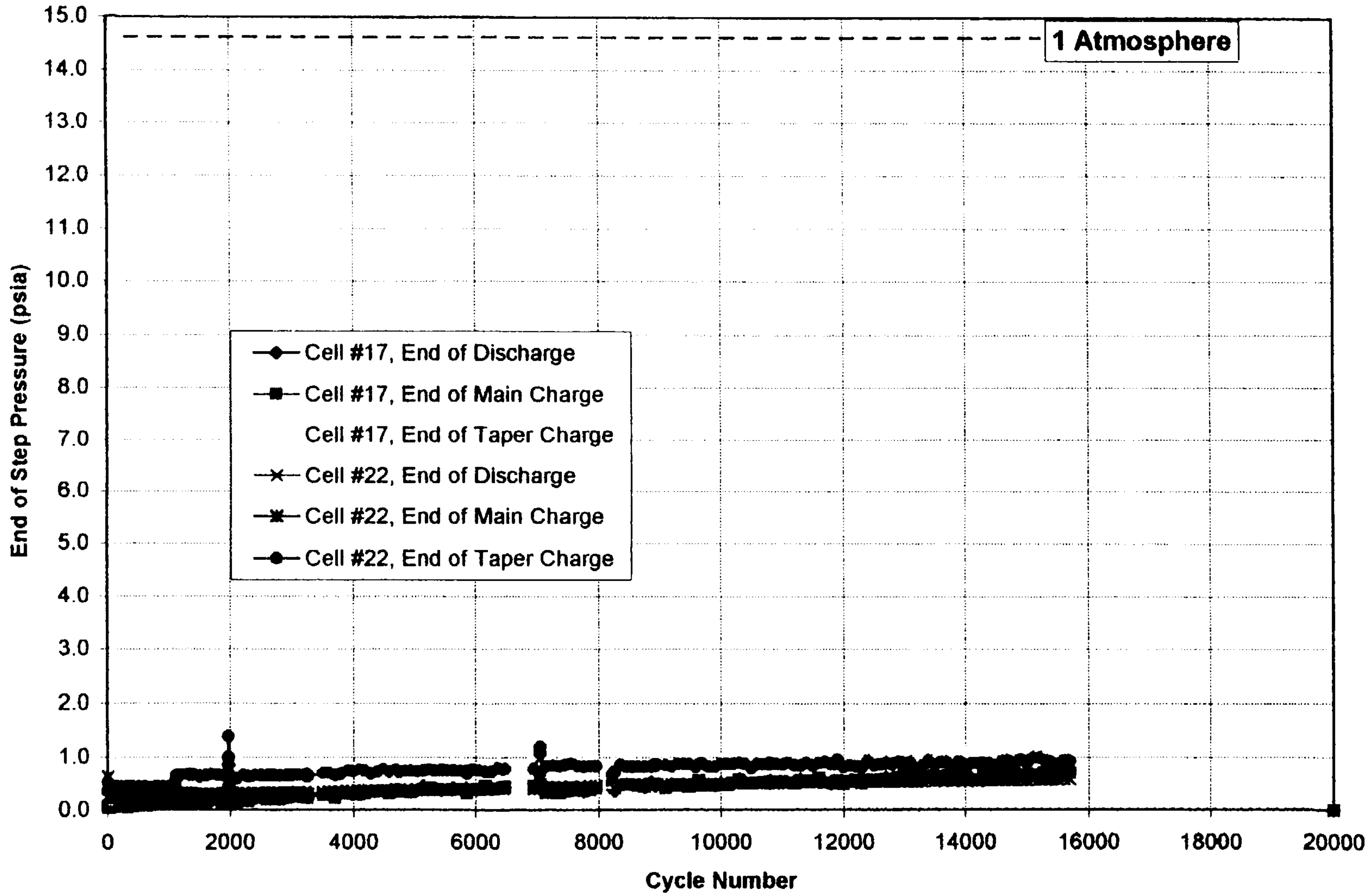
10°C Accelerated Internal Pressure



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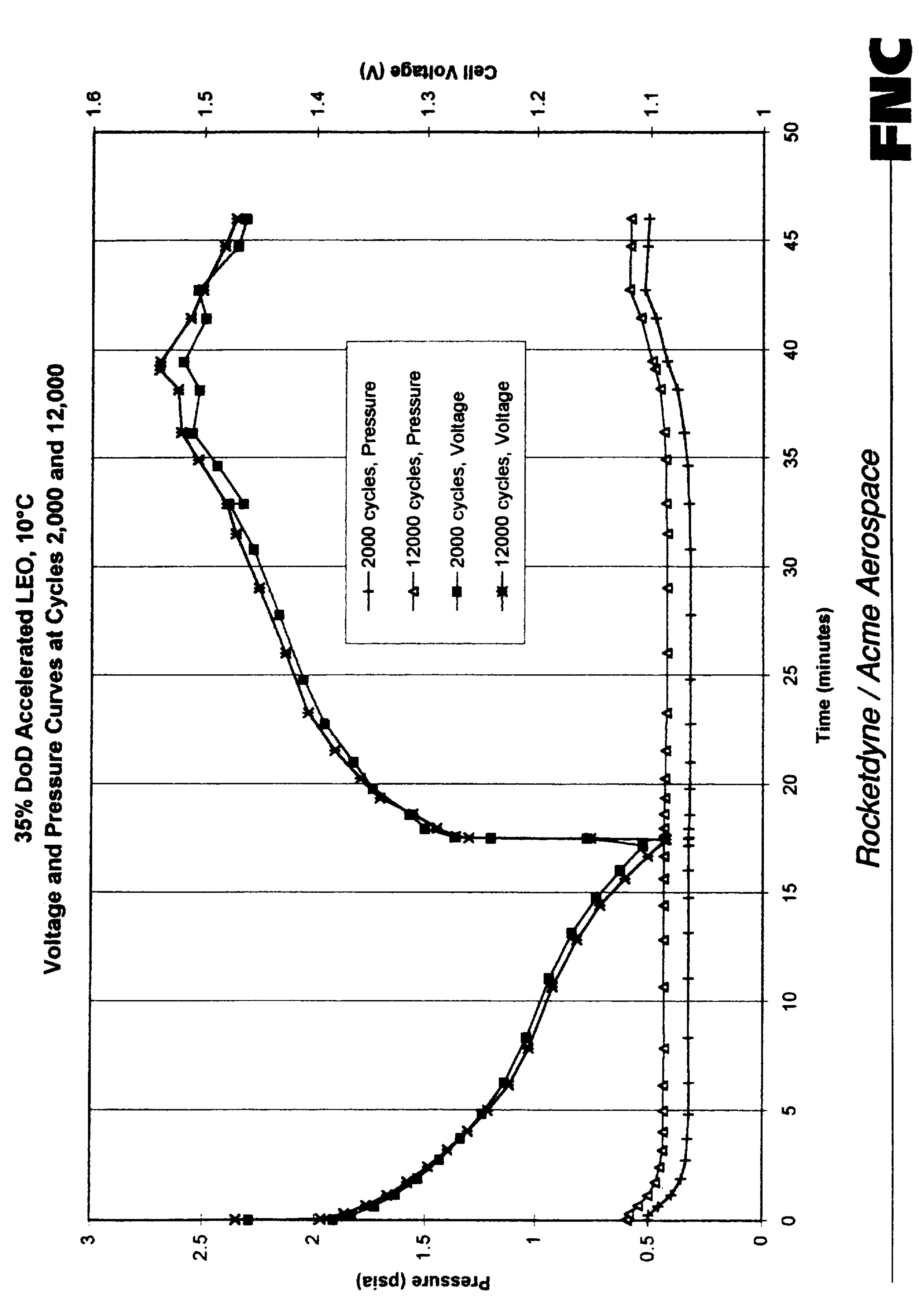
35% DoD Accelerated LEO, 10°C
Voltage and Pressure Curves at Cycles 2,000 and 12,000
Cell Voltage (V)
Pressure (psia)
Time (minutes)
2000 cycles, Pressure
12000 cycles, Pressure
2000 cycles, Voltage
12000 cycles, Voltage
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Conclusions

- Sealed Ni-Cd cells are not limited to 50 Ah with the FNC design
- Energy Densities of 40 Wh/kg in a conservative high Cd, high electroltye design have been demonstrated
- Uniform ATP data and LEO cycling performance is being demonstrated
- Internal cell pressures remain low under all conditions
- No conditioning is necessary under any LEO profile
- Accelerated LEO cycling exhibits performance well beyond traditional Space Ni-Cd cells
- The FNC shows promise for applications at higher charge and discharge rates, wider operating temperatures and deeper DOD than has been previously possible with traditional Space Ni-Cd cells.
- FNC offers lower cost, simplified system design and operating logistics, safer operation, comparable energy density to Ni/H2, resulting in a more economical choice for many applications

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