LIFE EVALUATION of 35AH Ni-Cd CELL in JAPAN

1991 NASA AEROSPACE BATTERY WORKSHOP

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INTRODUCTION

- The National Space Development Agency of Japan (NASDA) has been developing Ni-Cd cells for space use from 1985.
- Sanyo Electric Co., Ltd (Sanyo) have been responsible for the cell design, manufacturing, and initial tests, etc.
- The life of cells have been evaluated by NASDA in the Tsukuba Space Center (TKSC).
- The development is presently in the Qualification Test (QT) phase.
- The Flight Model (FM) cells for Engineering Test Satellite-6 (ETS-Ⅵ) is in the process of manufacturing.
- The design of the FM cells is same as QT cells.
- We present recent life-cycle data of 35AH Ni-Cd cells.

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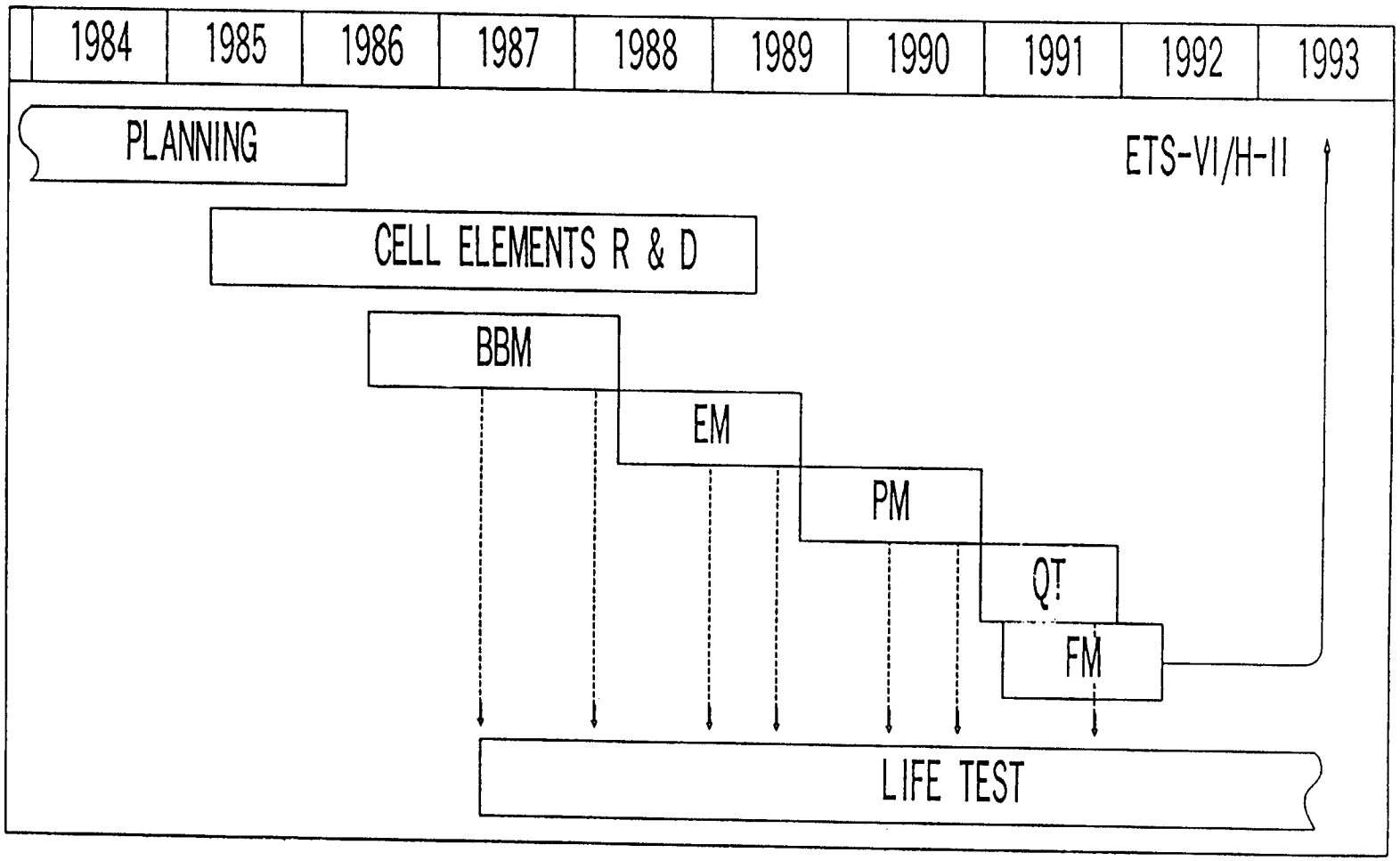
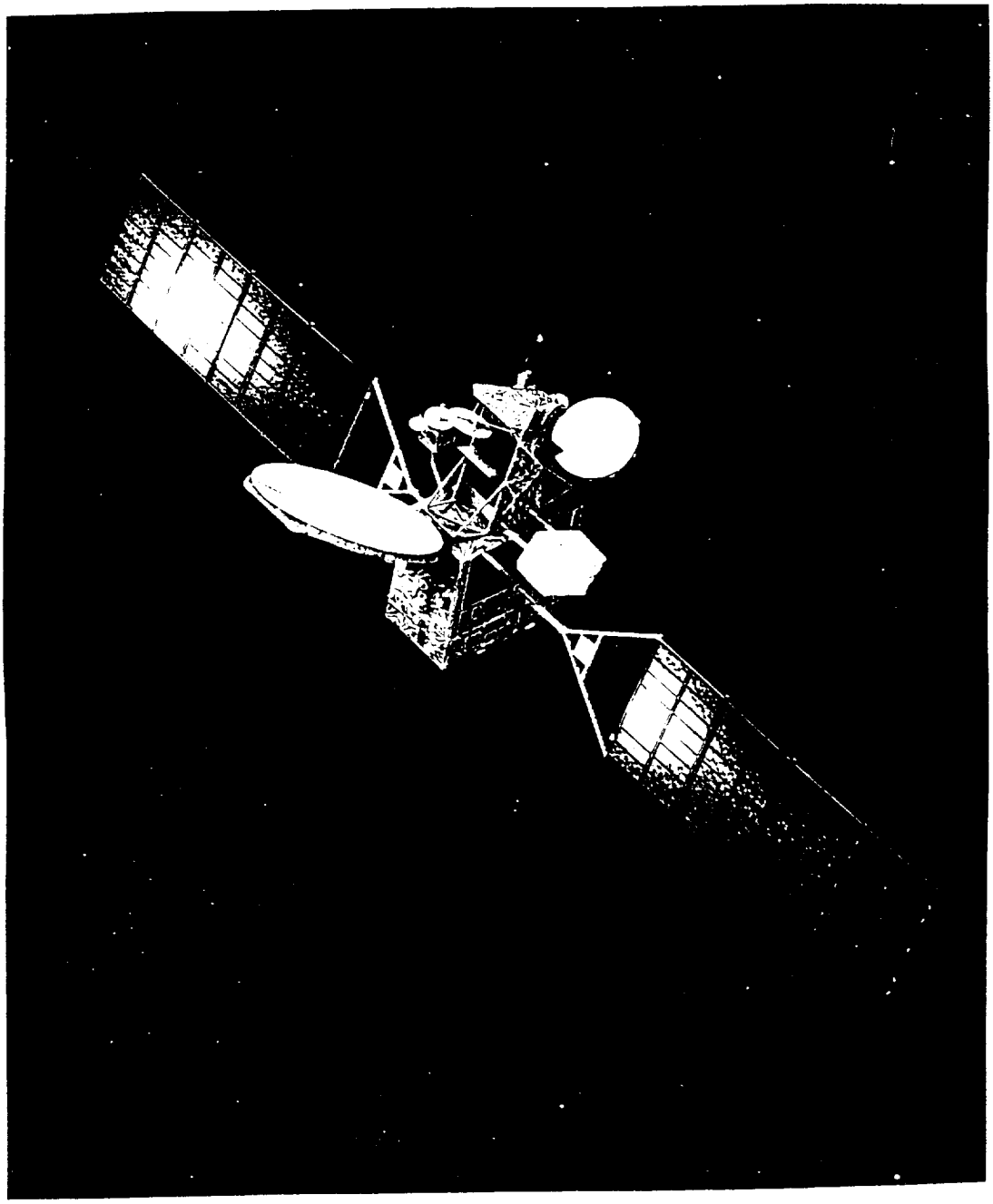
MILESTONE OF 35AH Ni-Cd CELL DEVELOPMENT



ENGINEERING TEST SATELLITE VI (ETS–VI)



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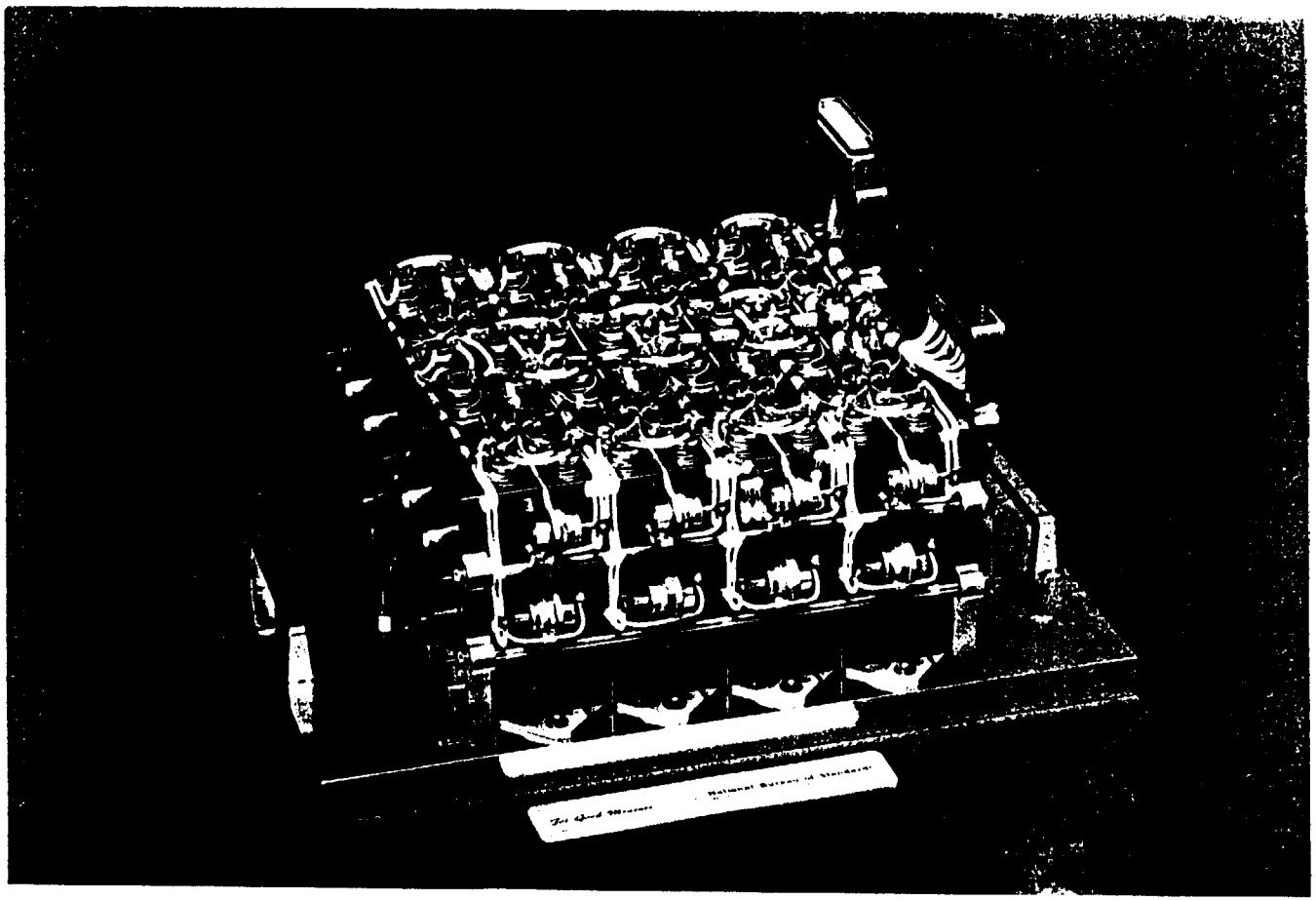
ETS－Ⅵ Ni-Cd BATTERY



＊Engineering Model

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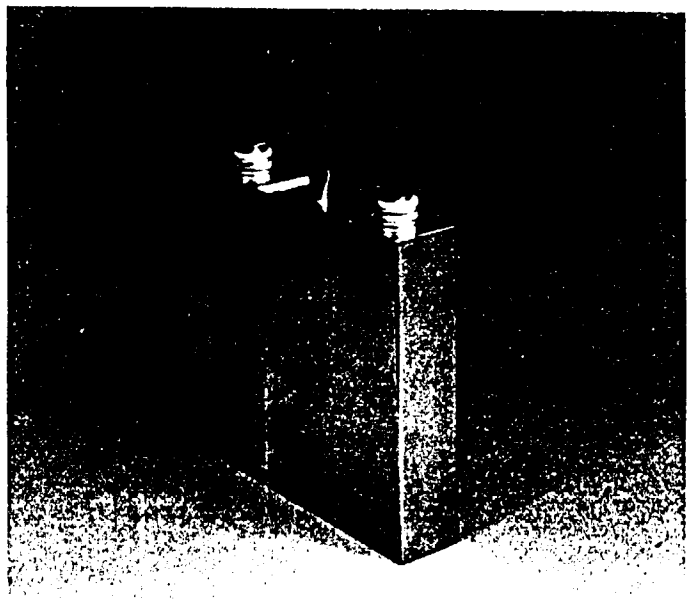
35AH SPACE Ni-Cd CELL

CELL MAJOR SPECIFICATIONS

Rated Capacity		35 AH
Mission	GEO	10Years, 1,000cycles
	LEO	3Years, 20,000cycles
Weight		max. 1050g
Energy Density		40WH/kg
Mechanical Strength	Burst Pressure	35kgf/cm^2
	Pressure Cycling	50,000cycles (0~3.5 kgf/cm^{2}G)



EXTERNAL VIEW OF Ni-Cd CELL

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CELL DESIGN

- In order to satisfy the satellite demands for high power, light weight, and long mission, electrodes with high sinter plate porosity, and high active material loading level (positive plate : 2.4 g/cc-void, and negative plate : 3.0 g/cc-void) were required.
- Nylon is used as separator according to the result of evaluation tests for separators.
- Precharge capacity of 12AH, and electrolyte weight of 98g have been chosen, according to the results of evaluation tests for precharge and electrolyte.

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CELL DESIGN

	(+)	(−)
Electrode Dimension	104.4 x 100 x 0.63mm	104.4 x 100 x 0.80mm
Sinter Plate Porosity	85 %	86 %
Loading Level	2.4 g/cc-void	3.0 g/cc-void
Number of Plate	13	14
Electrode Capacity	42.0 AH	72.8 AH
Capacity Ratio	1.73	
Separator	Nylon	
Precharge Capacity	12 AH	
Electrolyte	31%KOH 98g	
Cell Dimension	115.2H x 106.9W x 25.2Tmm (max.127Hmm)	
Cell Weight	max.1050g	
Cell Capacity	38.6AH	

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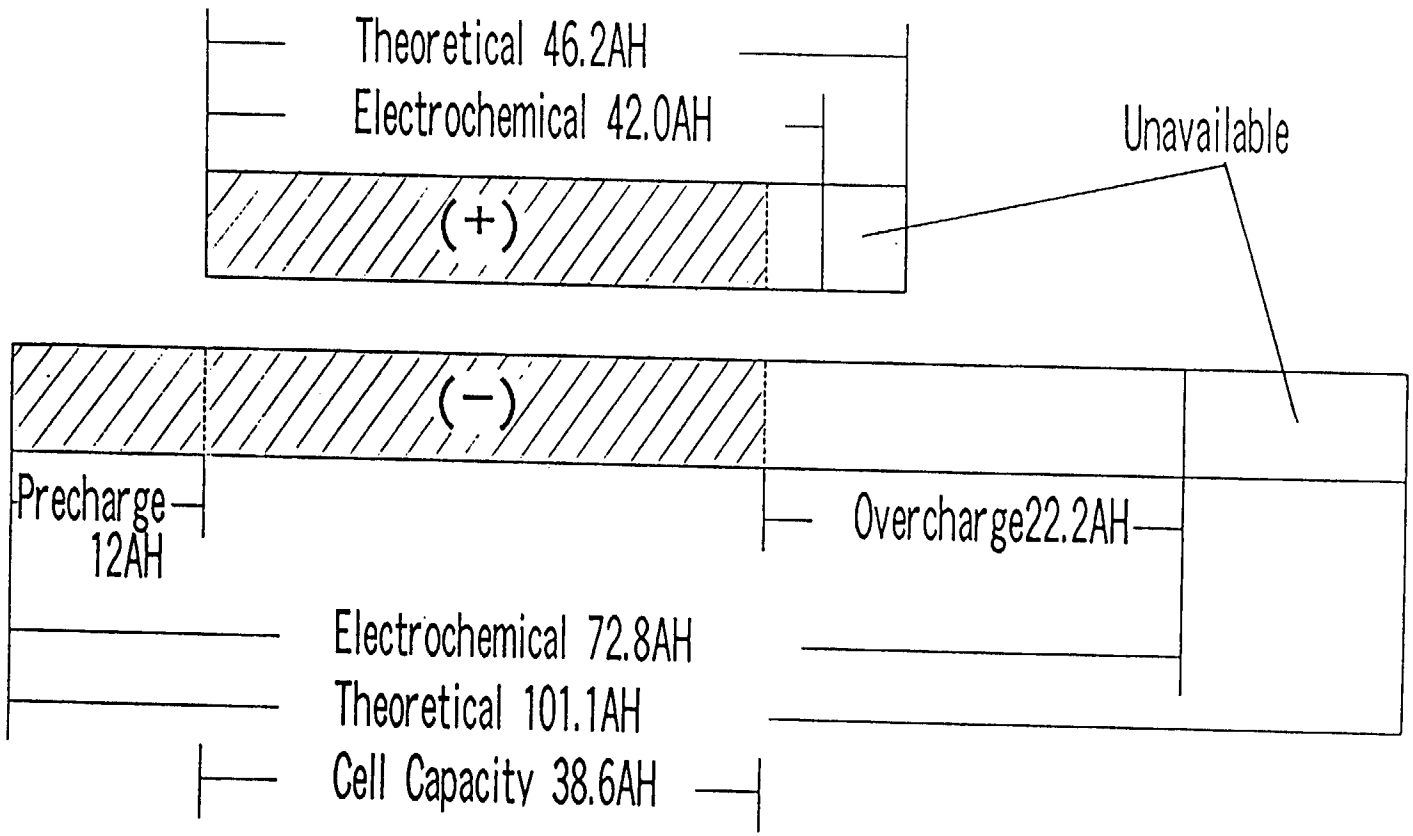
ELECTRODE CAPACITY DESIGN



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CELL INITIAL DATA

- The main initial tests of QT phase are as follows:
  - overcharge capacity test (-5℃, 20℃, 35℃)
  - high rate discharge test
  - internal impedance
  - alkaline leakage
  - open circuit voltage recovery
  - weight & dimensions check
  - some mechanical strength tests
- 94 sample cells have been used for these tests.
- Cell capacity, end of charge voltage, and weight data were distributed within narrow range.

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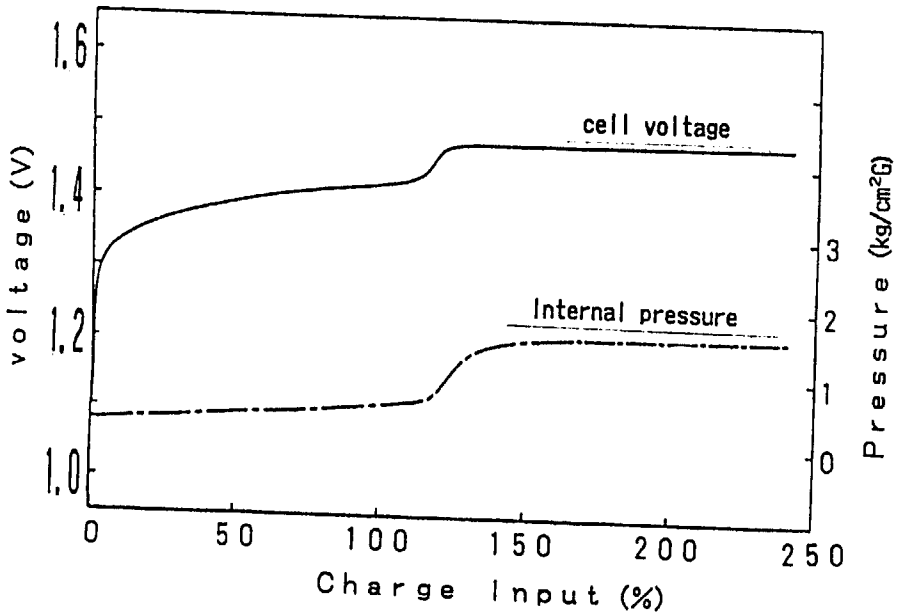
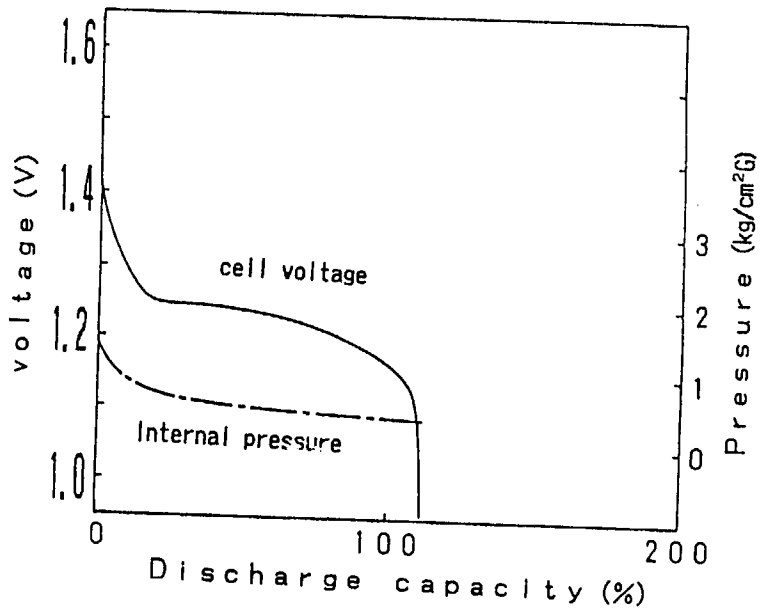
Ni-Cd CELL INITIAL DATA

CHARGE



DISCHARGE



TEST CONDITION

CHARGE	: 0.1 C for 24 Hours
DISCHARGE	: 0.5 C to 1 V
TEMP	: 20°C

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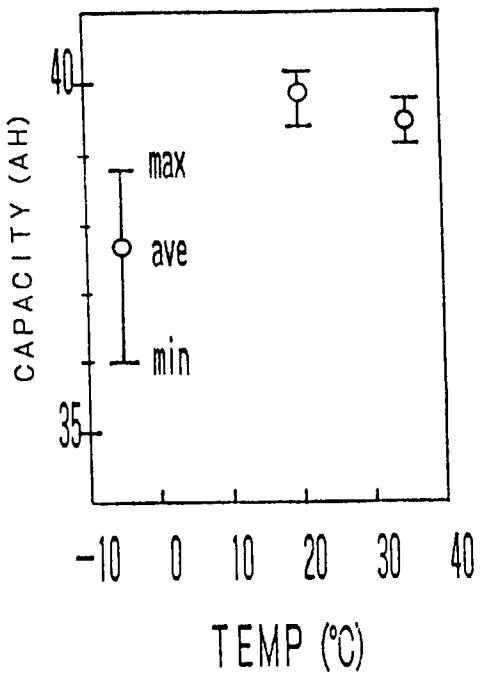
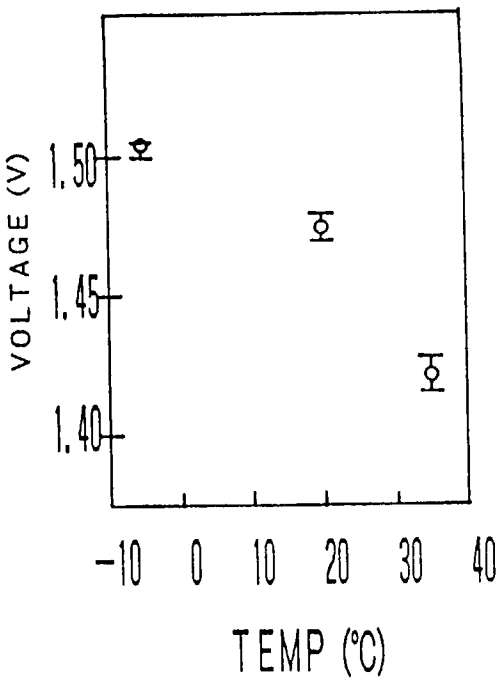
Ni-Cd CELL INITIAL DATA

- 94 sample cells have been used for initial tests of QT-phase.
- Capacity, EOCV, & Weight data are within narrow range.

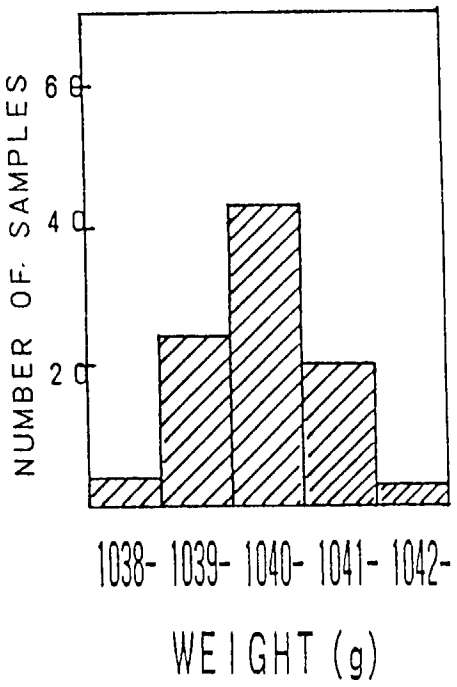
CELL CAPACITY



E O C V



CELL WEIGHT



TEST CONDITION CHARGE : 0.1C for 24 Hours (in −5℃, 0.05C for 48 Hours)
DISCHARGE : 0.5C to 1V

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BATTERY TEST FACILITY IN TSUKUBA SPACE CENTER

- NASDA has a battery test facility in TKSC, which consists of 4 equipment for Ni-Cd batteries, and 1 equipment for Ni-H2 batteries and for electrodes respectively.
- Each test equipment is independently controlled by each computer.
- Test data is transfered from each computer to a data server, and finally collected on the hard-disc automatically.
- Test data and plotter are available for NASDA engineers and technicians by using any 4 data-terminals.
- A total of 24 independent tests on Ni-Cd batteries can be performed by the 4 equipment.
- For temp control, temp-controlled chambers can control cell temperature within a ±2℃ range of the expected temp.
- Also cooling plates are available especially for battery assembly tests.

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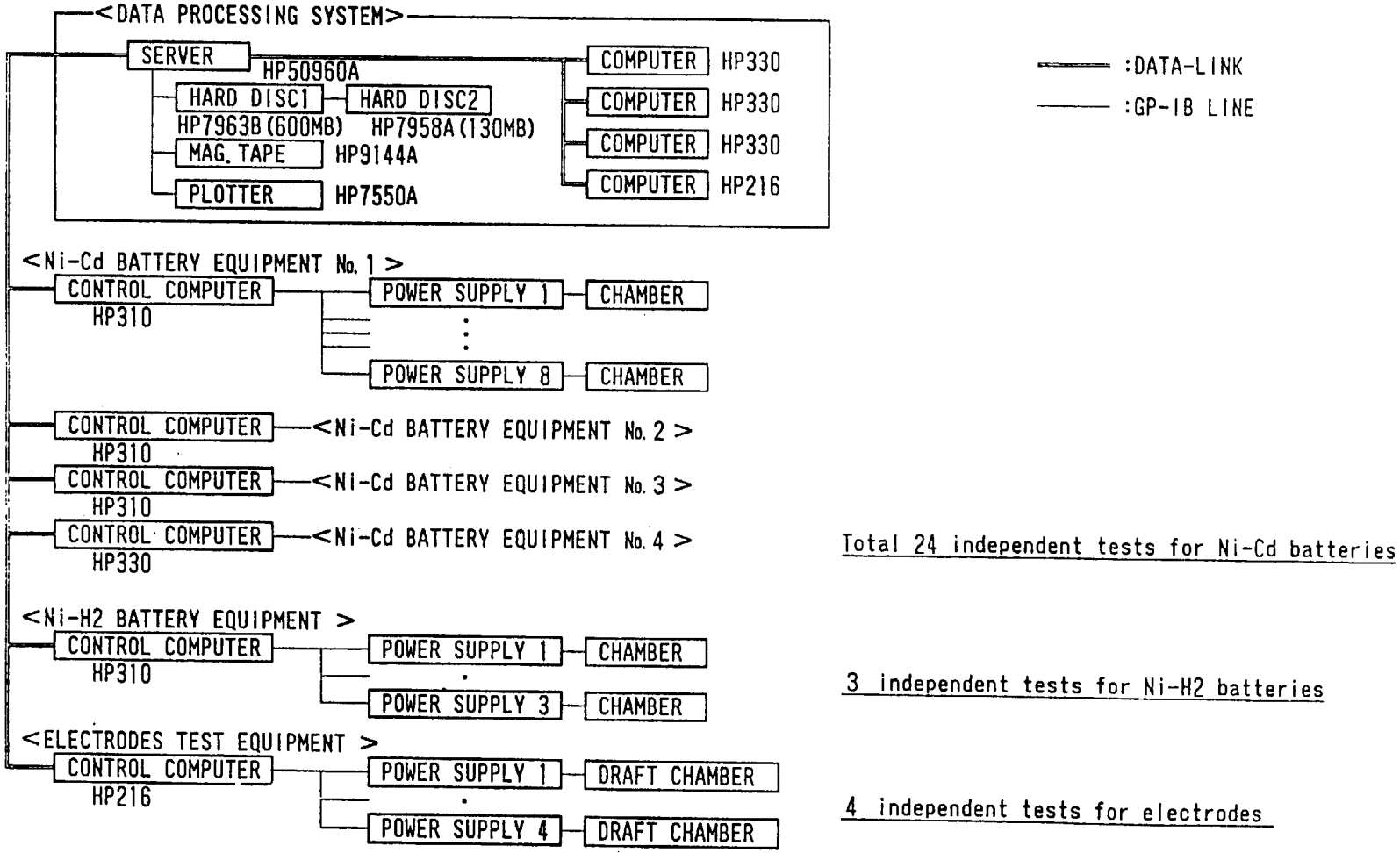
BATTERY TEST SYSTEM IN TSUKUBA SPACE CENTER



Total 24 independent tests for Ni-Cd batteries

3 independent tests for Ni-H2 batteries

4 independent tests for electrodes

BATTERY TEST at NASDA TKSC

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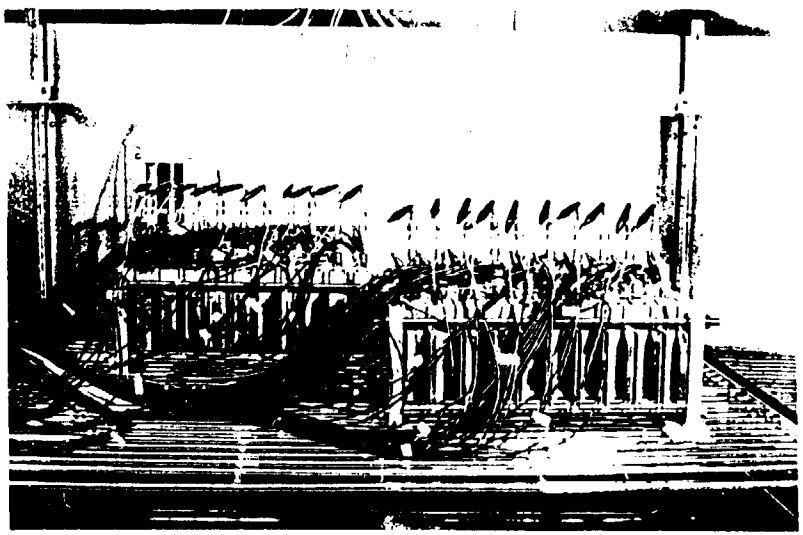
筑波宇宙センター　Ni-Cd 電池寿命試験



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LIFE TEST DATA

- BBM phase cells were our first trial to make high capacity cells, so most of samples failed.
- With the exception of the BBM cells, most of the sample cells with normal design have shown good performance, especially the EM1 cells are the best ones.
- EM2 phase cells have been used for evaluation of precharge, electrolyte, and separator washing method.
- PM1 phase cells have been evaluated for accelerated cycling.
- PM2 phase cells have been evaluated for 4 types of tests which were GEO test, LEO test, trickle charge test, battery assembly GEO test.

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LIFE TESTS OF 35AH Ni-Cd CELL

Oct 8, 1991

No.	SAMPLE	TEST TYPE	DOD	TEMP	NUMBER of CYCLE
1	BBM (*1)	GEO	60%	20℃	1186 (Finished)
2	BBM	LEO	25%	20℃	17334
3	BBM (*2)	ACCELERATED	60%	30℃	1429 (Finished)
4	EM1	GEO	60%	20℃	1530
5	EM1	LEO	25%	20℃	15235
6	EM2	GEO	60%	20℃	1350
7	EM2	LEO	25%	20℃	12517
8	EM2	TRICKLE CHG	——	20℃	677 day
9	EM2 ASSY	LEO	20%	5℃	7560
10	PM1	ACCELERATED	80%	20℃	1968
11	PM2	GEO	60%	20℃	370
12	PM2	LEO	25%	20℃	2795
13	PM2	TRICKLE CHG	——	20℃	175 day
14	PM2 ASSY	GEO	50%	20℃	210

*1: It was finished because EOCV reached 1.6V
*2: It was finished because EODV dropped to 1V

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TEST CONDITION

THE TYPICAL TEST CONDITIONS ARE AS FOLLOWS

TEST TYPE / CONDITION	G E O	L E O	ACCELERATED
Charge	0.1C, 9 Hours	0.3C, 52.5 min	0.3C, 220min
Discharge	0.5C, 1.2 Hours	0.5C, 30 min	0.5C, 96min
DOD	60 %	25 %	80 %
Charge return	150 %	105 %	138 %
Reconditioning(*1)	every 45 cycles	DO NOT	DO NOT
Capacity test (*2)	every 45 cycles	about every 5000cycles	about every 1000cycles

*1 : Reconditioning is 1/80C discharge to 1 Volt, and then charge return is 0.1C for 16Hours.

*2 : Capacity test is 0.5C discharge to 1 Volt, and then charge return is 0.1C for 16Hours.

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EVALUATION OF SEPARATOR

- BBM cells have been used for this test.
- Candidates for the separator material were nylon, polypropylene (PP), and poly-phenylene sulfide (PPS).
- The test condition was accelerated cycling with higher temperature than for the other tests.
- As the result of this test, EODV of PP & PPS cells dropped to 1V before 1,000 cycles, but EODV of the nylon cell was stable.
- On the other hand, EOCV of PP & PPS cells were stable, but the EOCV of the nylon cell was rising a little

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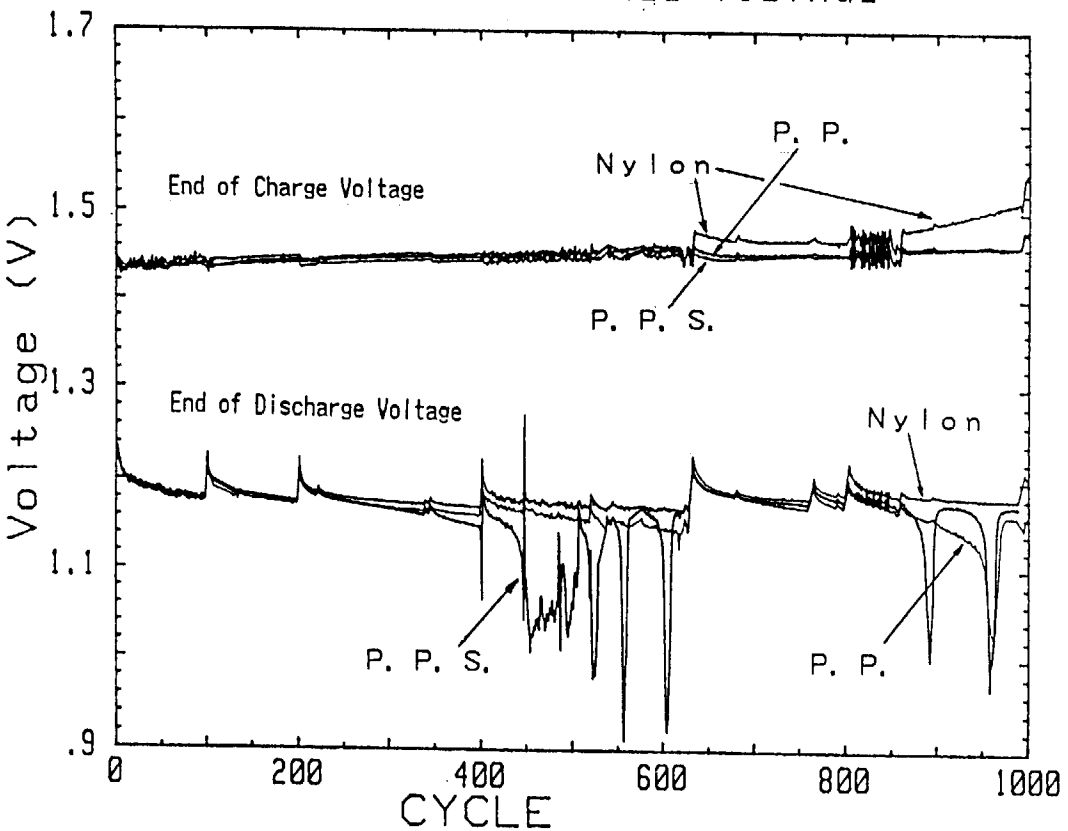
EVALUATION OF SEPARATORS

The current cells are using a nylon separator,
since PP & PPS separator cells could not keep normal EODV.

CYCLE TREND OF CELL VOLTAGE



SEPARATOR CANDIDATES

	Nylon	PP	PPS
Thickness	0.21 mm	0.21 mm	0.22 mm
Weight	87g/m²	79g/m²	84g/m²
Retention	326%	282%	320%

TEST CONDITION

Charge : 0.3C, 144min
Discharge : 0.5C, 72min
DOD : 60%
Temp : 30°C

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EVALUATION OF ELECTROLYTE & PRECHARGE

The range of electrolyte weight in this test was 98-119g, and the range of precharge was 7-22AH.

Electrolyte evaluation

- When comparing the electrolyte under constant precharge at 12AH, excess of electrolyte caused more stable capacity, but caused higher pressure,
- We selected a 98g electrolyte, because the cell of even 98g electrolyte cells have enough stability of capacity, and it was the lowest pressure.

Precharge evaluation

- When comparing the precharge under constant electrolyte at 106g, higher precharge caused the rising of EOCV and EOCP.
- We selected a 12AH precharge, because the 12AH-precharge cell has a lower EOCP, and is more stable in capacity than the 7AH-precharge cell.

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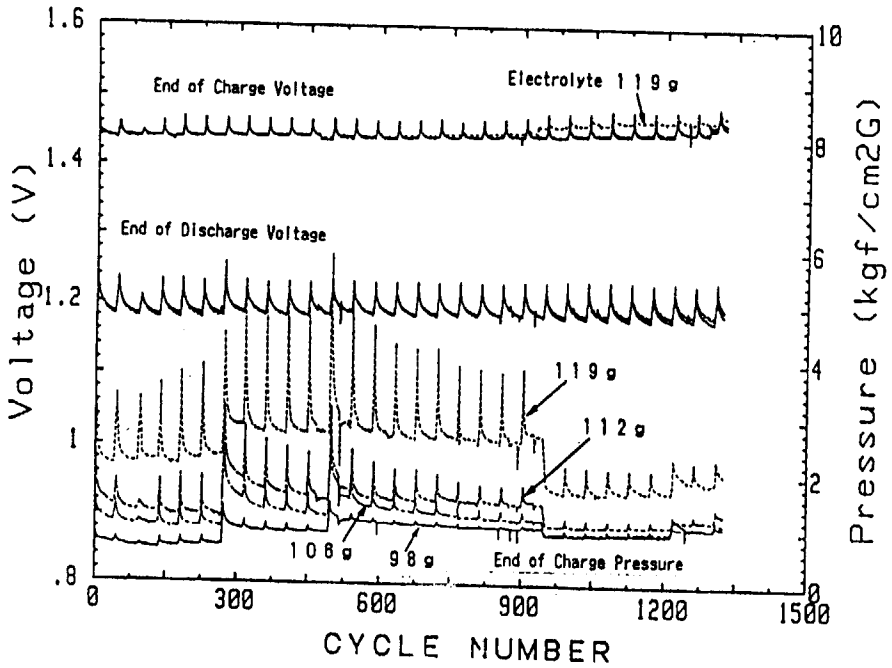
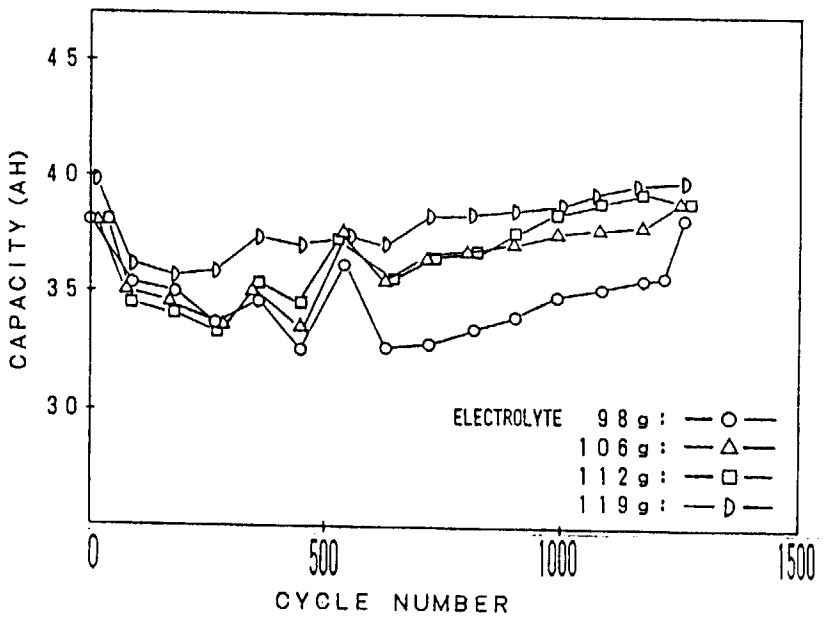
EVALUATION OF ELECTROLYTE

An over 98g electrolyte is neccessary for stability of capacity.
But excess of electrolyte causes higher internal pressure.

CYCLE TREND OF VOLTAGE & PRESSURE



CYCLE TREND OF CAPACITY



TEST CONDITION : SAME AS GEO TEST

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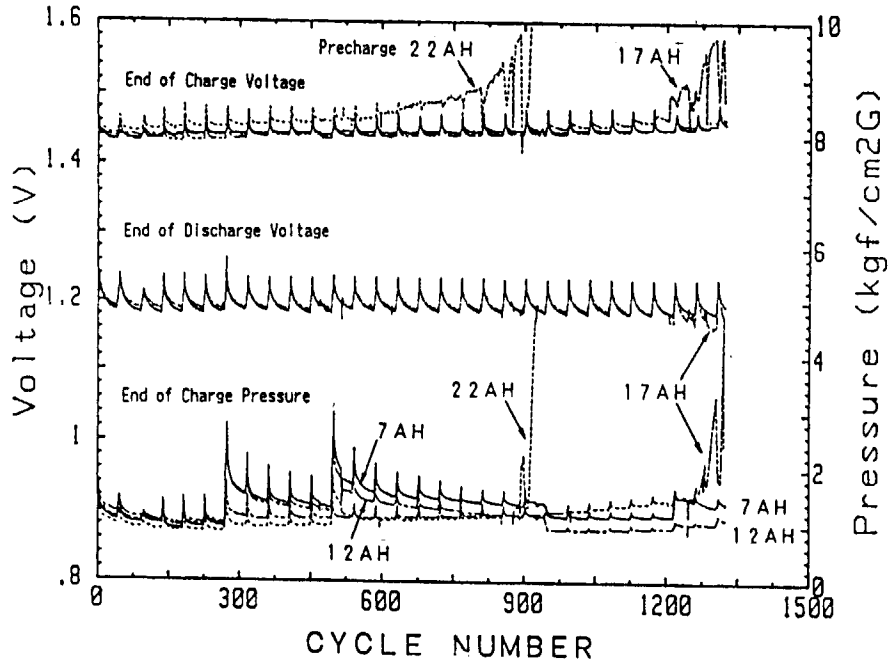
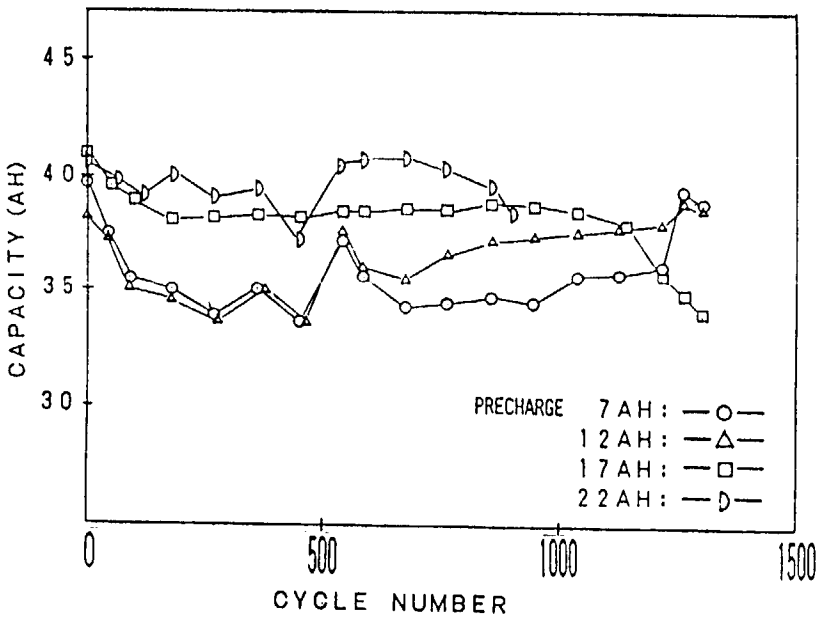
EVALUATION OF PRECHARGE

Higher precharge causes the rise of EOCV.
The current design cell has 12AH precharge.

CYCLE TREND OF VOLTAGE & PRESSURE



CYCLE TREND OF CAPACITY



TEST CONDITION : SAME AS GEO TEST

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TYPICAL LIFE DATA

GEO test

- EM1 cells data is presented as typical GEO life data.
- Voltage & pressure data were stable, but the capacity degradation was observed after about 1,000cycles.
- It satisfied mission-required cycles, and presently cycling is still continuing.

LEO test

- Also in LEO test, EM1 cells data is typical LEO data.
- The present cycle number is about 15,000 cycles.
- It shows little rising of EOCV & pressure, and little degradation of EODV & capacity.
- Mission requirements for LEO cycling are over 20AH of capacity, and over 1.05V of EODV after 20,000 cycles.

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TYPICAL LIFE DATA (cont.)

Battery assembly LEO test

- The sample battery is built from 16 cells of the EM2 phase.
- Charging method is changed to taper charge from constant current charging when battery (of 16 cells) voltage reaches to 23.82V, and total charging time is 60 minutes.
- Each cell voltage shows uniformity under taper charging, during these 7,500 cycles.

Accelerated test

- PM1 cell have been used for this test.
- At 225 cycles, it was changed from GEO test of DOD60% to Accelerated test of DOD80% bacause we wanted to know the effects of some treatments earlier.
- As the result, the cycle life of current design cell was about 1,400 cycles, and we knew some treatment effects.

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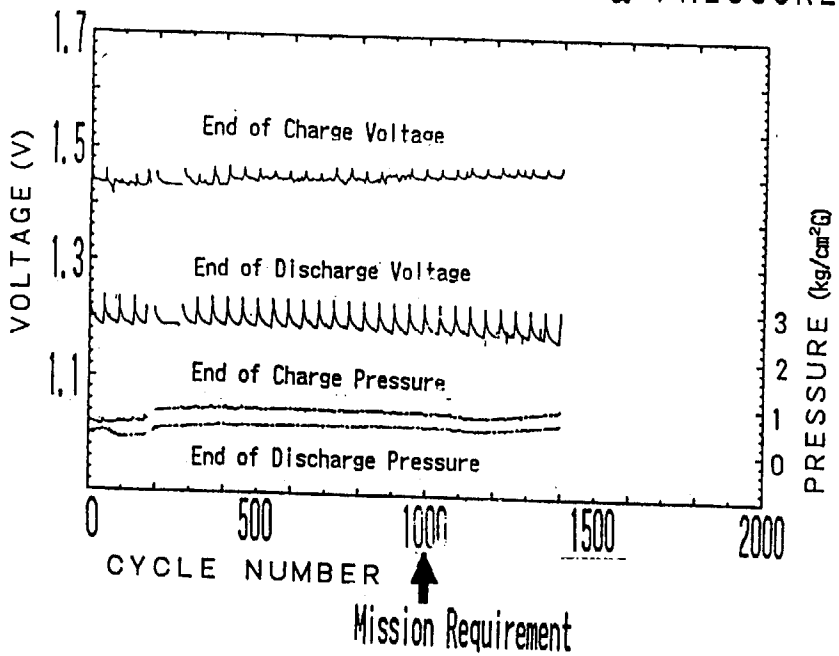
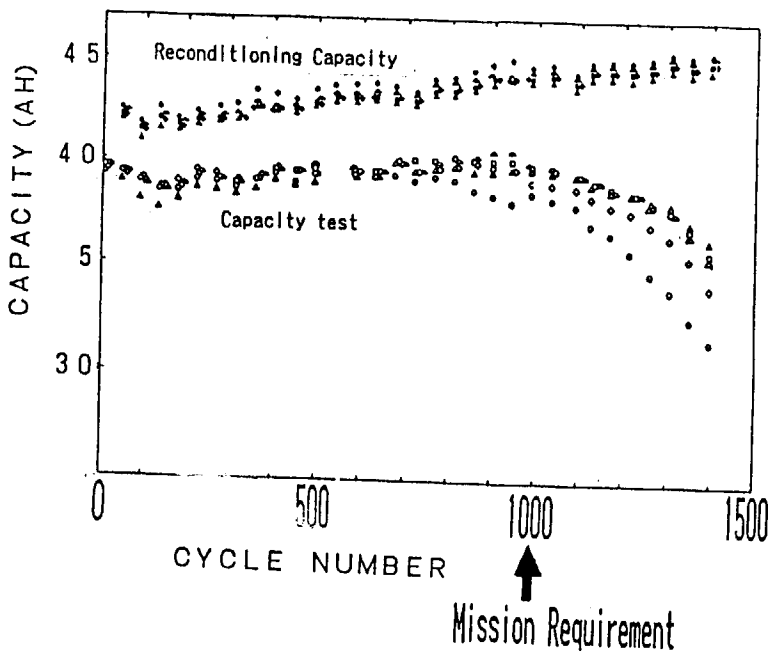
TYPICAL LIFE DATA (GEO SIMULATION)

Cell voltage, pressure, and capacity is stable during the mission-required cycles

CYCLE TREND OF VOLTAGE & PRESSURE



CYCLE TREND OF CAPACITY



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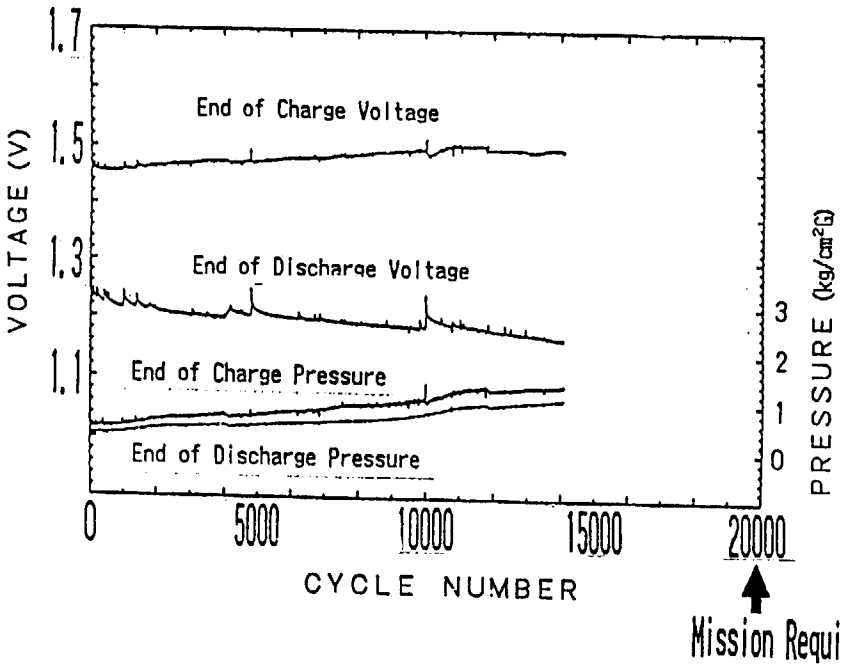
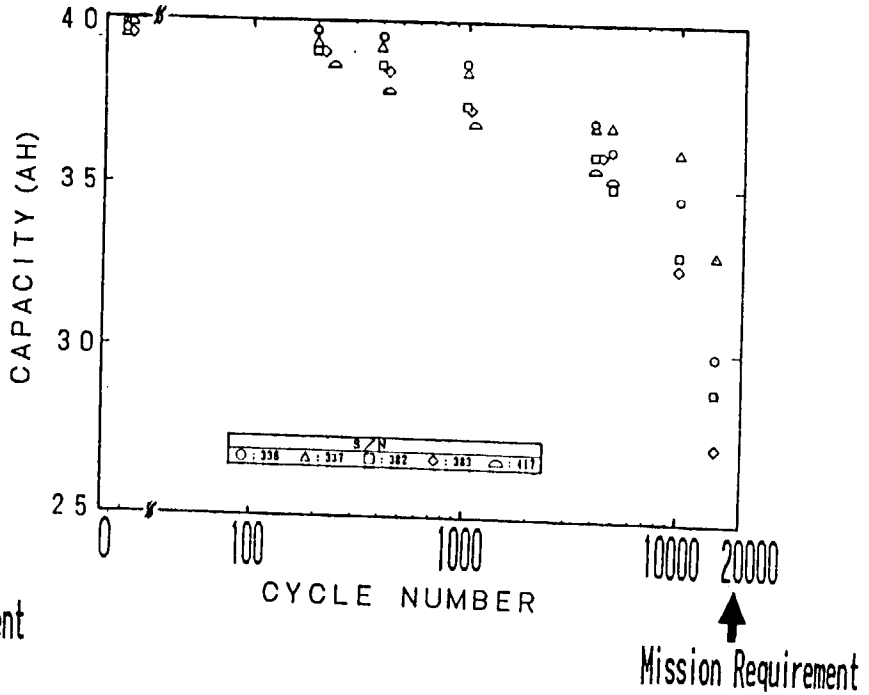
TYPICAL LIFE DATA (LEO SIMULATION)

The expected result is over 20AH of capacity,
and over 1.05V of EODV after 20,000 cycles.

CYCLE TREND OF VOLTAGE & PRESSURE



CYCLE TREND OF CAPACITY



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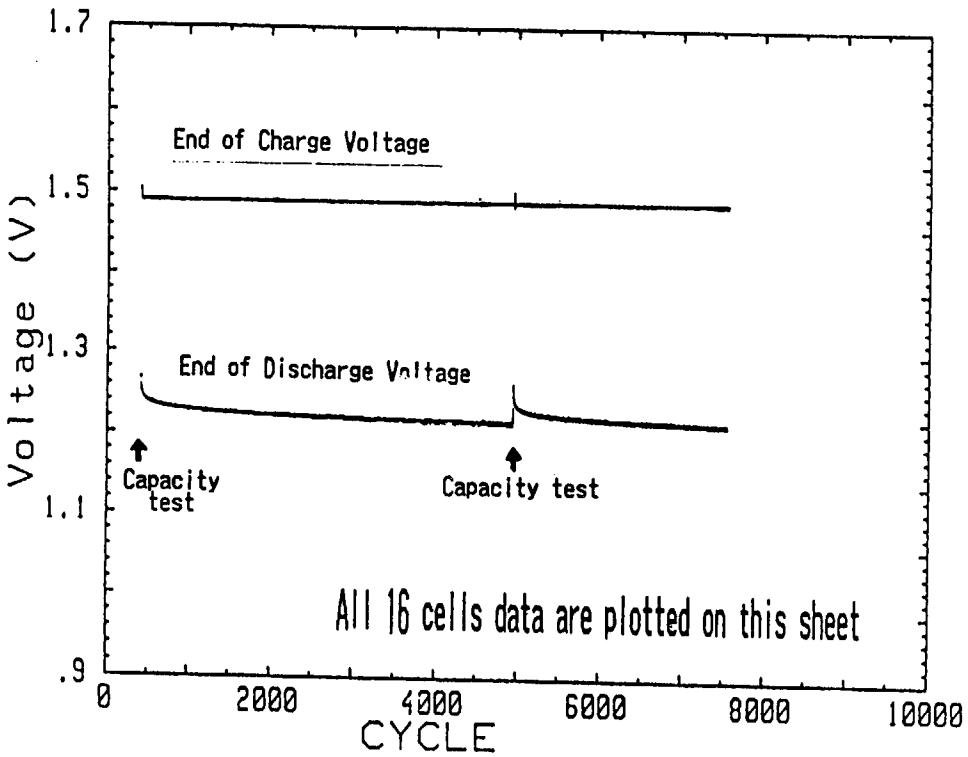
TYPICAL LIFE DATA (BATTERY ASSY LEO)

The uniformity of EOCV & EODV of each cell was observed under constant voltage charging with battery assy.

CYCLE TREND OF CELL VOLTAGE



TEST CONDITION

Charge (taper charge)
- constant rate : 0.3C
- limit voltage : 23.82V/16cells
- charge time : 60min

Discharge : 0.33C, 36min

DOD : 20%

Temp : 5℃

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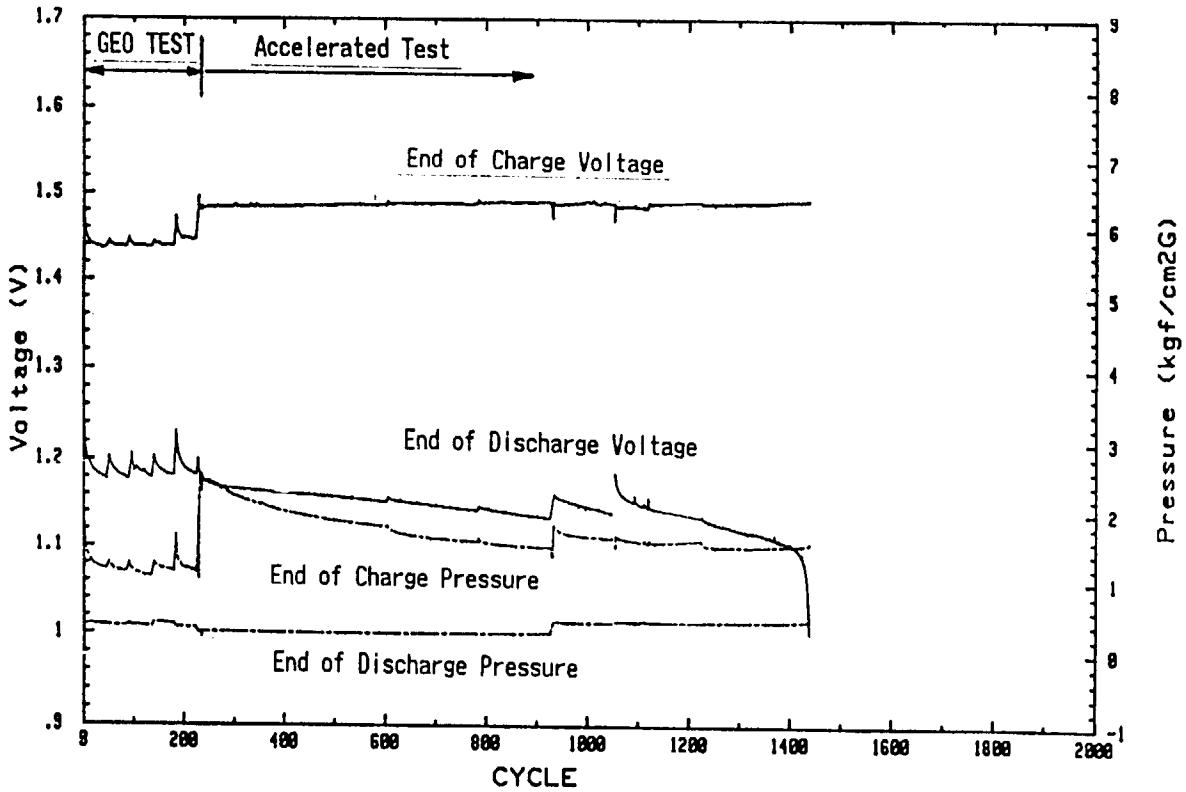
TYPICAL LIFE DATA (ACCELERATED CYCLE)

The life of over 1,000 cycles was obtained in the case of DOD 80% cycling.

CYCLE TREND OF VOLTAGE & PRESSURE



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ADVANCED CELL DESIGN

We have tried some treatments, and two methods of these treatments were good & effective for cell performance.

Alkaline washing for separator

- Current design cells showed degradation of capacity after 1,000 cycles in GEO cycling, but the cells using the washed separator showed stability in capacity.
- Both cells have no difference in charge and discharge voltage presently.
- This washing method is simply to wash the separators in an alkaline solution and next reduce it by water, and dry it.

Organic compound treatment for negative plates.

- In the accelerated cycling, the cycle life of current design cells was about 1,400 cycles, but the cells treated with organic compound on the negative plates have an over 2,000 cycles life, and this cycling is still continuing.

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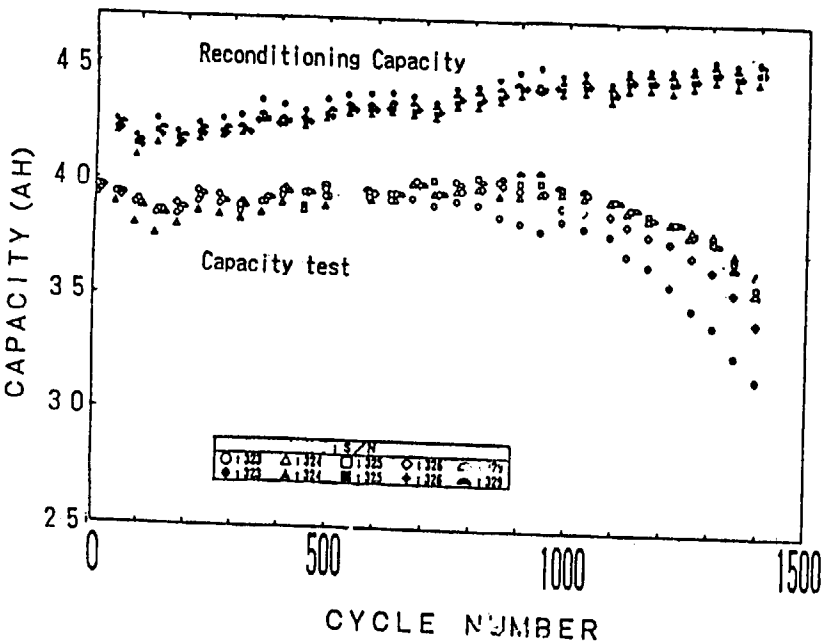
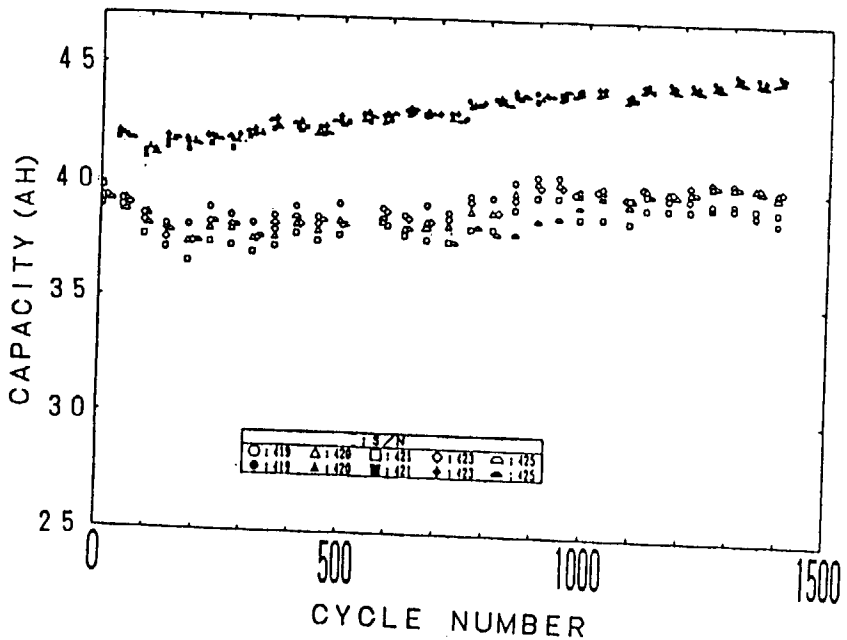
ADVANCED CELL DESIGN (1)

ALKALINE WASHING FOR SEPARATOR IS EFFECTIVE FOR STABILITY OF CAPACITY.

CURRENT DESIGN CELL → ADVANCED → ALKALINE WASHING FOR SEPARATOR





TEST CONDITION : SAME AS GEO SIMULATION

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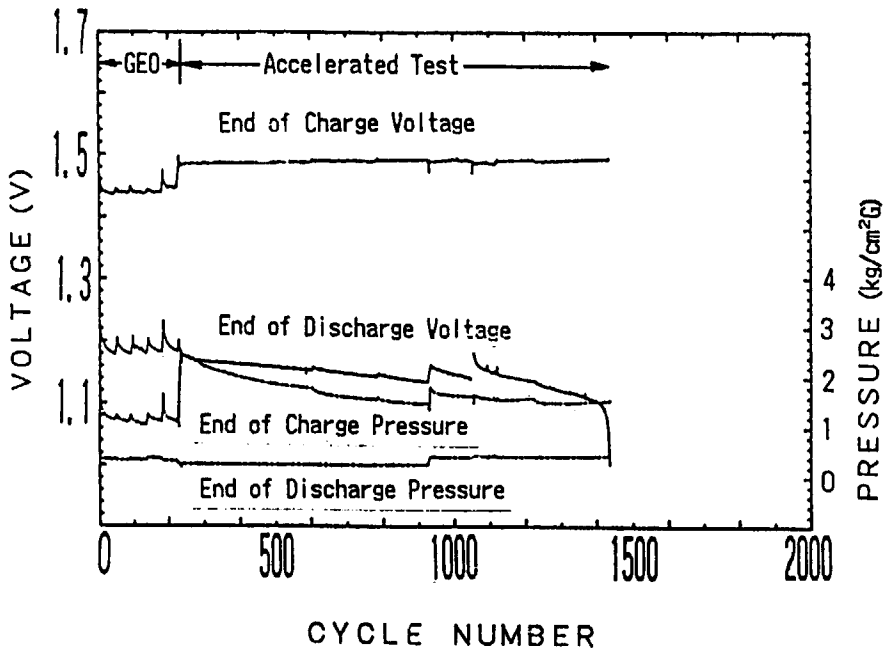
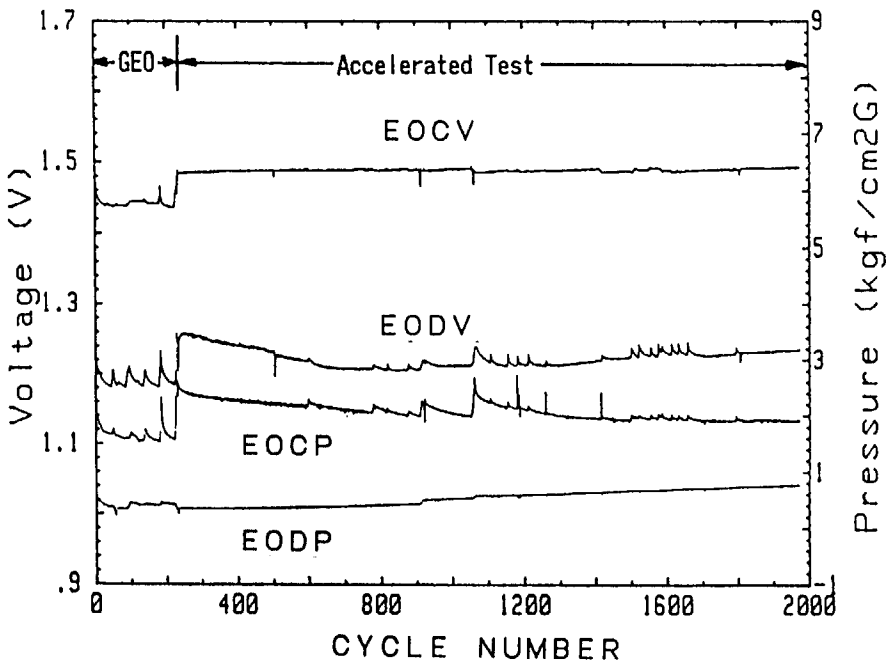
ADVANCED CELL DESIGN (2)

ORGANIC COMPOUND TREATMENT FOR NEGATIVE ELECTRODE IS EFFECTIVE FOR LIFE OF CELL

CURRENT DESIGN CELL



ADVANCED NEGATIVE ELECTRODE TREATMENT



TEST CONDITION : SAME AS ACCELERATED CYCLING

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CONCLUSION

- We think this development of 35AH Ni-Cd cell for space use will be completed successfully.
- We think the fruits of this development are high energy density, long life, and verifying of some effective treatments.

- Energy density of 40WH/kg is higher than conventional Ni-Cd cells.
- The GEO cycle life of 1,000 cycles that is one of mission requirements was verified, so we will use these cells in ETS-6 confidently.
- Presently the LEO test is at about 15,000 cycles, of course, we expect to achieve the 20,000 cycles successfully, since we want to use these cells for the LEO mission of ADEOS which is our test satellite launched in 1995.

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CONCLUSION (cont.)

- It was verified that two treatments were effective for the cell performance.
- But these methods were not adopted for flight cell design of ETS-6, since there is not enough data in the time when the flight cell design might be decided.
- We will adopt it for future cell design.

Our future program on Ni-Cd cells is as follows:

1. Inprovement of 35AH cells (and use in ADEOS)
2. Development of 25AH cells based on 35AH cells
3. Development of 50AH cells with another design

SUMMARY

1. High energy density of 40WH/kg with current design was developed

2. The life of current design cell is as follows:
   - GEO Test (DOD 60%) --- over 1,400 cycles
   - LEO Test (DOD 25%) --- over 15,000 cycles
   - Accelerated Test (DOD 80%) --- 1,400 cycles

3. The following methods are effective for increasing the cycle life in the advanced cell design.
   - Alkaline washing for separator
   - Organic compound treatment for negative electrode

NASDA
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FUTURE PROGRAM

1. Inprovement of 35AH cells (and use in ADEOS)
2. Development of 25AH cells based on 35AH cells
3. Development of 50AH cells with another design