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DEVELOPMENT
of
NICKEL-METAL HYDRIDE CELL
An Update

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DEVELOPMENT OF NICKEL METAL-HYDRIDE CELL

OVERVIEW

NASDA BATTERY DEVELOPMENT SCHEDULE

EVALUATION OF COMMERCIAL Ni-MH CELLS

LEO CYCLE TEST

GEO CYCLE TEST

DEVELOPMENT OF Ni-MH CELL FOR SPACE USE

CELL DESIGN

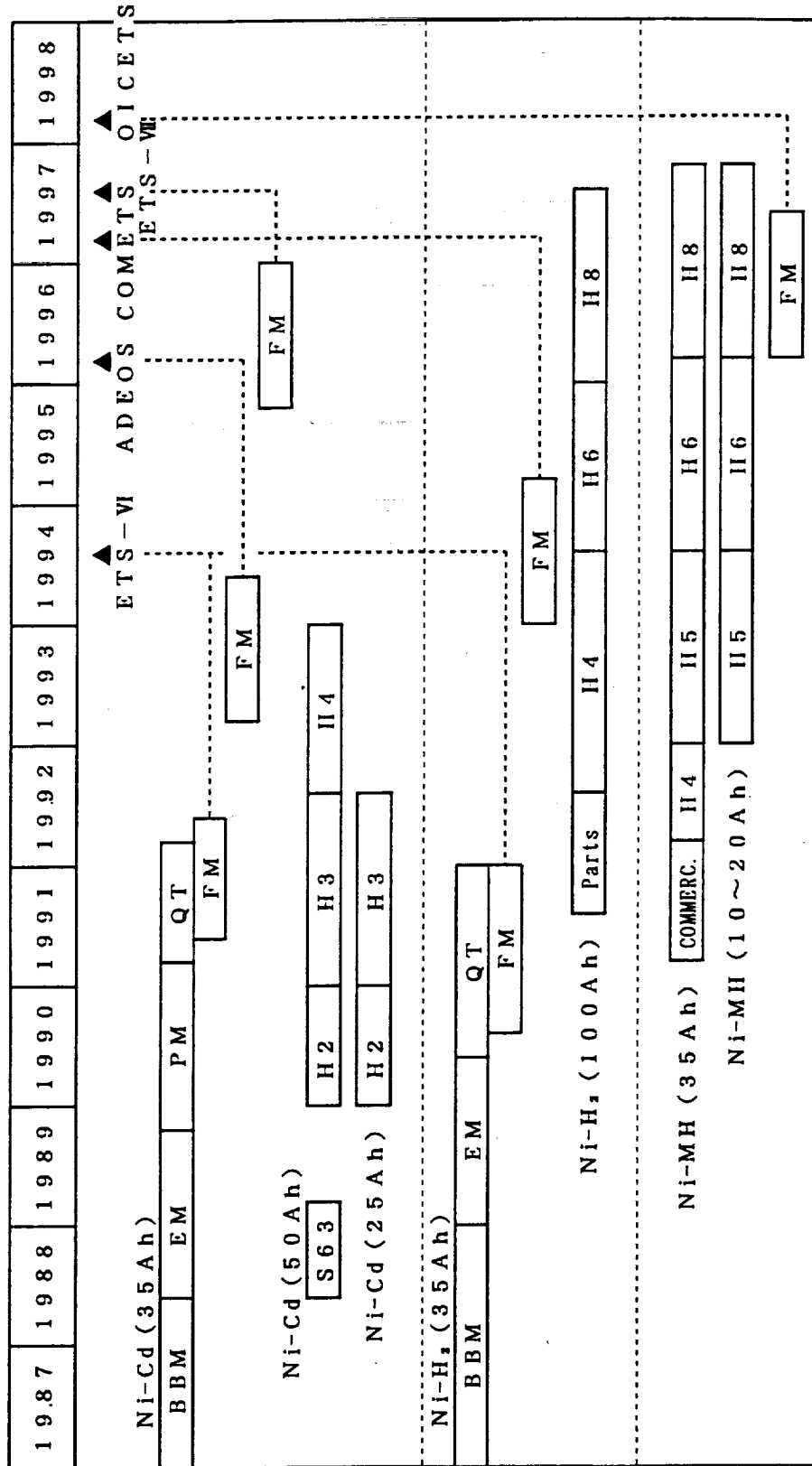
INITIAL CHARACTERISTICS

TREND OF LEO CYCLE TEST UP TO 3,000 CYCLES



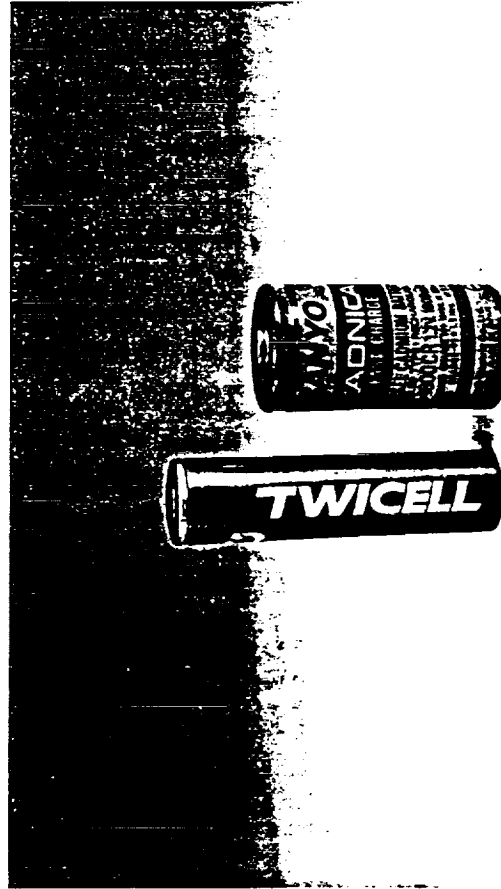
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SCHEDULE OF BATTERY DEVELOPMENT IN NASDA



SAMPLE SPECIFICATIONS

	Ni-MH	Ni-Cd
Capacity	2.2Ah	1.8Ah
MODEL No.	HR-4/3A	N-1800CR
Diameter	17 mm	26 mm
Height	67 mm	50 mm
Weight	51 g	80 g



Ni-MH

Ni-Cd

EXTERNAL VIEW OF SAMPLES

TEST CONDITIONS OF LIFE TEST

CONDITION	TEST TYPE	G E O	L E O
CELL		5 Ni-MH + 5 Ni-Cd	5 Ni-MH + 5 Ni-Cd
CHARGE		0.1C, 9 hours	0.3C, 52.5 min
DISCHARGE		0.5C, 1.2 hours	0.5C, 30 min
DOD		60 %	25 %
CHARGE RETURN		150 %	105 %
TEMPERATURE		20°C (COOLING PLATE TEMP.)	
CAPACITY CHECK	RECONDITIONING CAPACITY (*1)	RESIDUAL CAPACITY (*2)	
	FULL-CHARGED CAPACITY (*3)	FULL-CHARGED CAPACITY (*3)	
	EVERY 45 CYCLES	ABOUT EVERY 5,000 CYCLES	

(C = 2.2A)

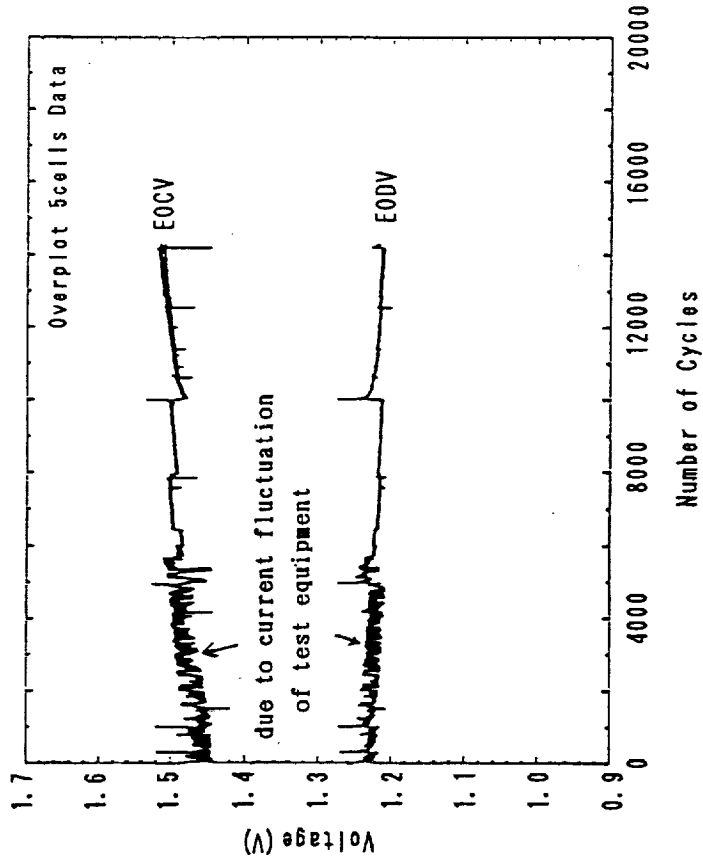
- * 1 : Reconditioning Capacity is obtained by 1/80C discharge to 1 Volt after GEO cycling charge.
- * 2 : Residual Capacity is obtained by 0.5C discharge to 1 Volt after LEO cycling charge.
- * 3 : Full-charged Capacity is obtained by 0.5C discharge to 1 Volt after full-charging with 0.1C for 16hours.



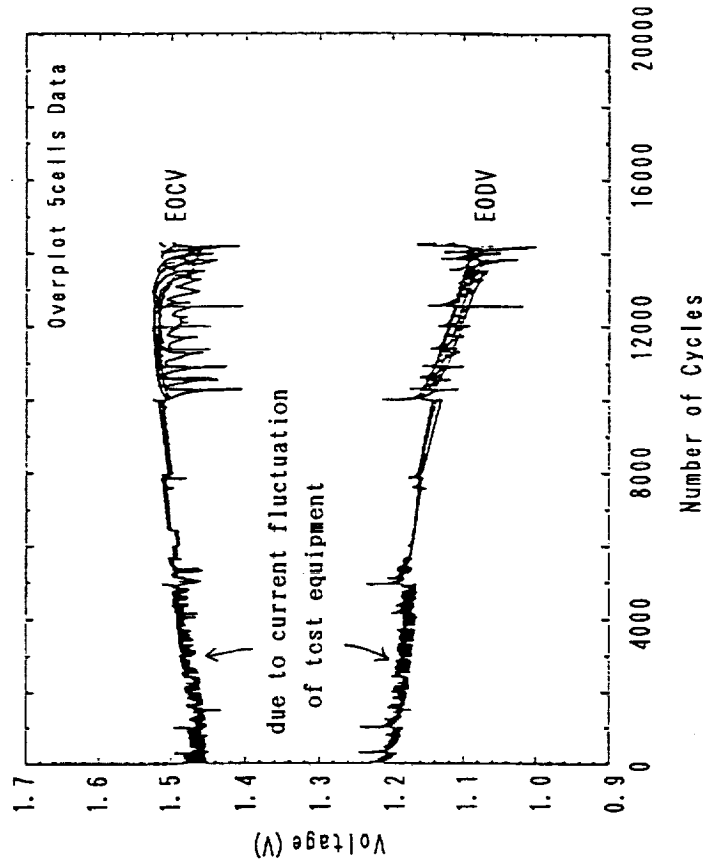
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TREND OF EOCV & EODV ON LEO TEST (COMMERCIAL)

NI-MH CELLS

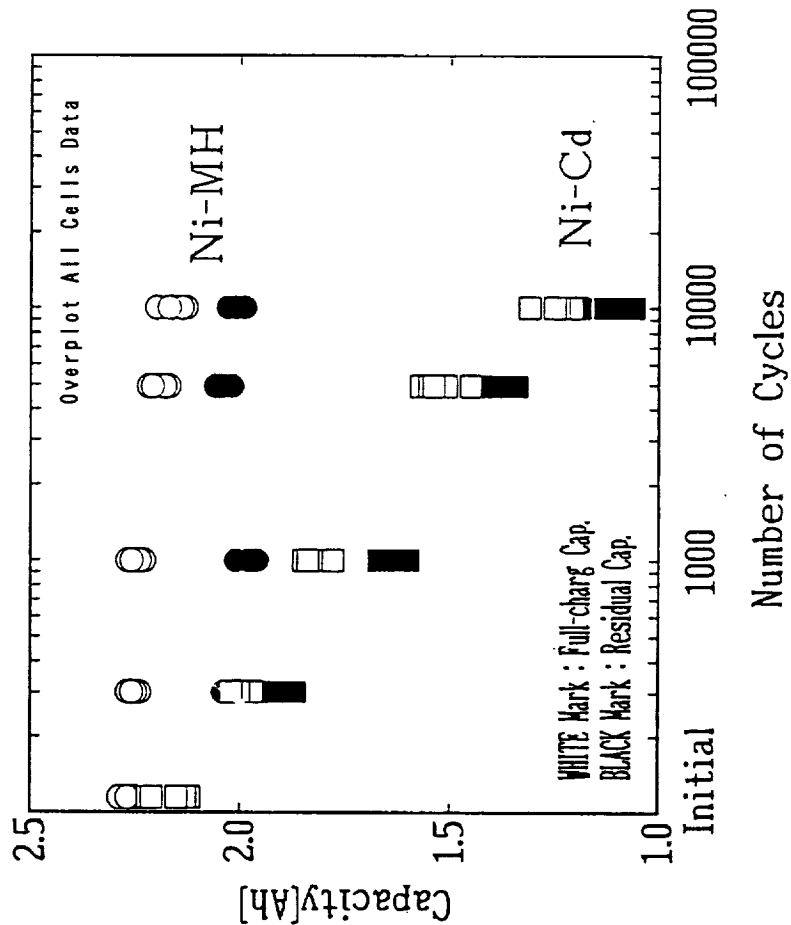


NI-Cd CELLS



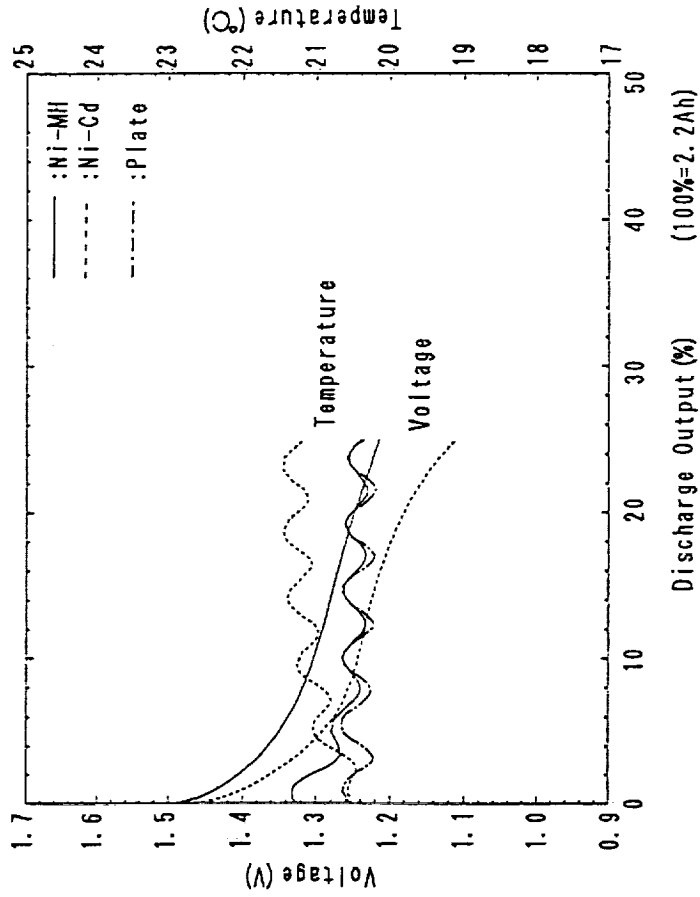
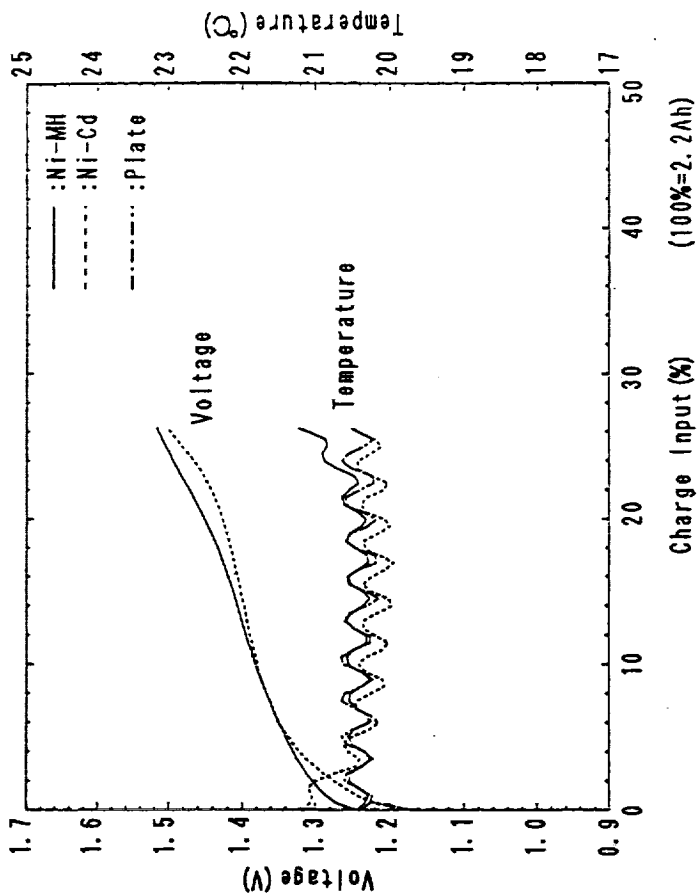
THE COMMERCIAL NI-MH CELLS HAVE GOOD PERFORMANCE WITH RESPECT TO STABILITY OF EOCV AND EODV

TREND OF CAPACITIES



THE COMMERCIAL NI-MH CELLS HAVE GOOD PERFORMANCE ABOUT CAPACITY REMAINING ESPECIALLY

CHARGE & DISCHARGE CHARACTERISTICS IN CYCLING
AT 14020 CYCLES



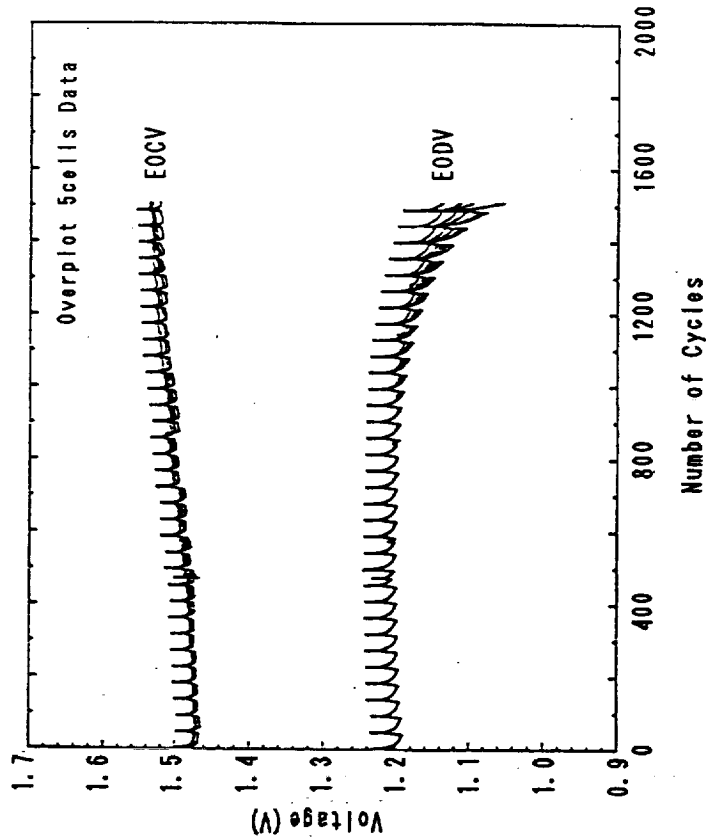
TEST CONDITION / CHARGE : 0.3C FOR 52.5 MINUTES
DISCHARGE : 0.5C FOR 30 MINUTES (DOD: 25%)
PLATE TEMP: 20°C



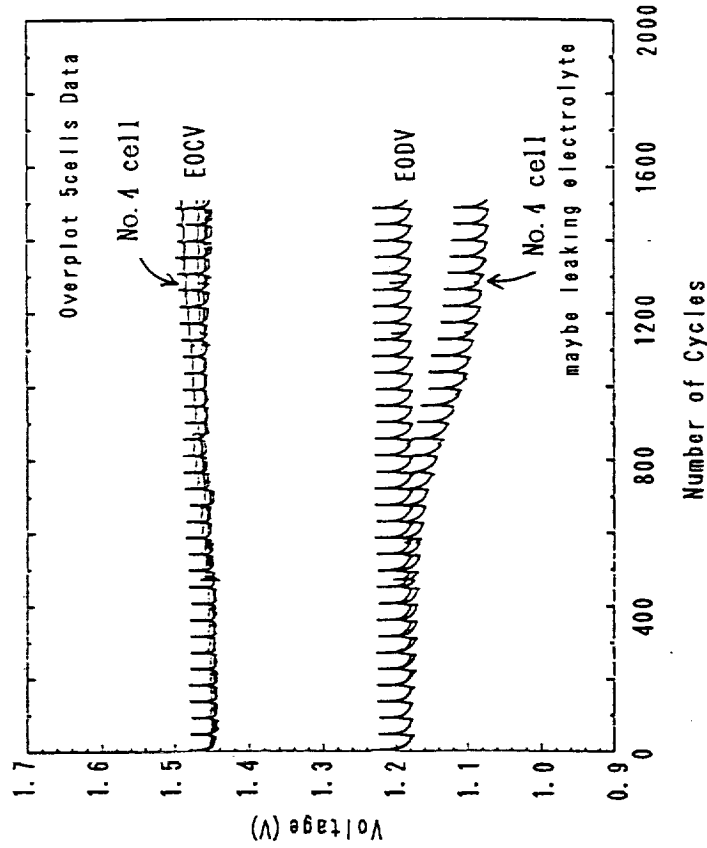
NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN

TREND OF EOCV & EODV ON GEO TEST (COMMERCIAL)

Ni-MH CELLS



Ni-Cd CELLS



LEAKING OF HYDROGEN GAS WAS ALSO OBSERVED AT EACH EOC
FROM AROUND 1,300 CYCLES



DEGRADATION OF COMMERCIAL NI-MH CELLS ON GEO

OVERCHARGE VOLTAGE INCREASE SO FAR AS
HYDROGEN GAS IS EVOLVED AT MH ELECTRODE



INTERNAL PRESSURE EXCEEDS THE LIMIT OF RESEALABLE SAFETY VENT



LEAK OCCURRENCE

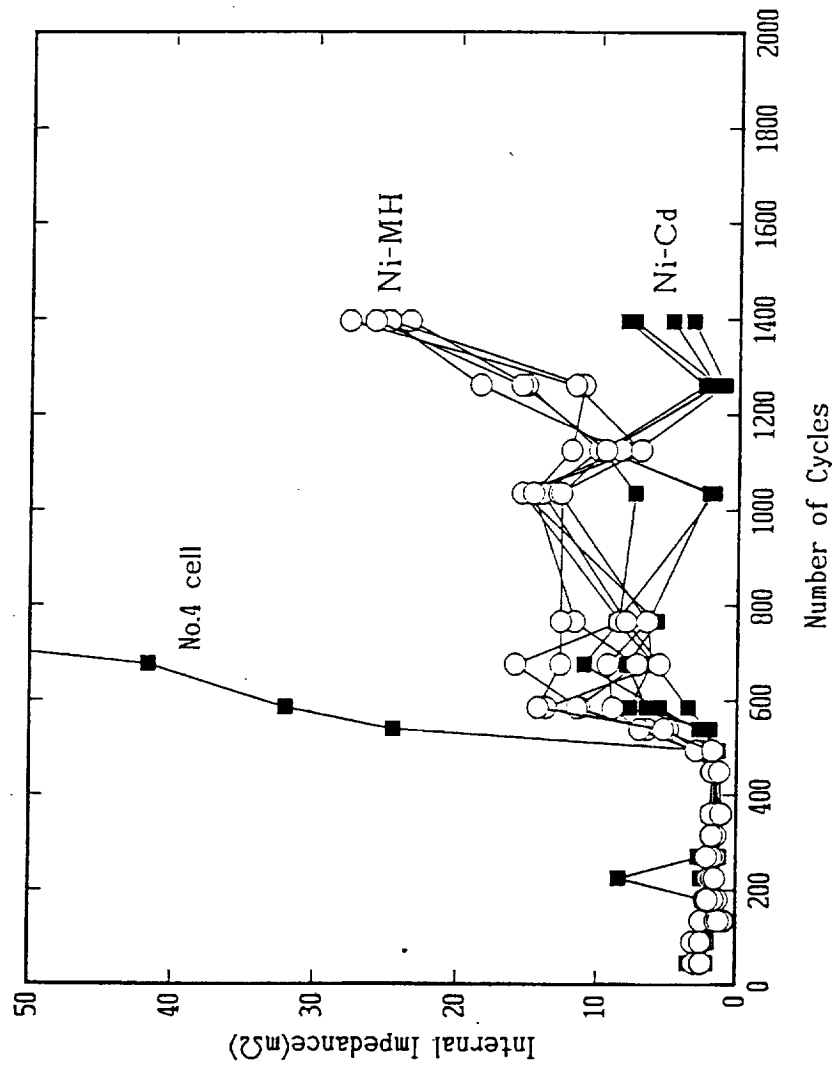


THE AMOUNT OF ELECTROLYTE DECREASE



DOWNWARD TREND OF EODV
(INTERNAL IMPEDANCE INCREASE)

TREND OF INTERNAL IMPEDANCE @ 1KHZ



INCREASE OF INTERNAL IMPEDANCE ALSO INDICATES LOSS OF ELECTROLYTE



FAILURE MODE OF COMMERCIAL Ni-MH CELLS ON GEO

DEGRADATION (SUCH AS OXIDATION) OF MH ELECTRODE



LOSS OF HYDROGEN ABSORBING CAPACITY



INCREASE OF OVERCHARGE VOLTAGE

THE RESULTED PHENOMENA ARE SIMILAR TO
LOSS OF OVERCHARGE PROTECTION ON Ni-Cd CELL

- EOCV INCREASE
- EOCP (DUE TO HYDROGEN GAS) INCREASE



EVALUATION OF COMMERCIAL Ni-MH CELLS

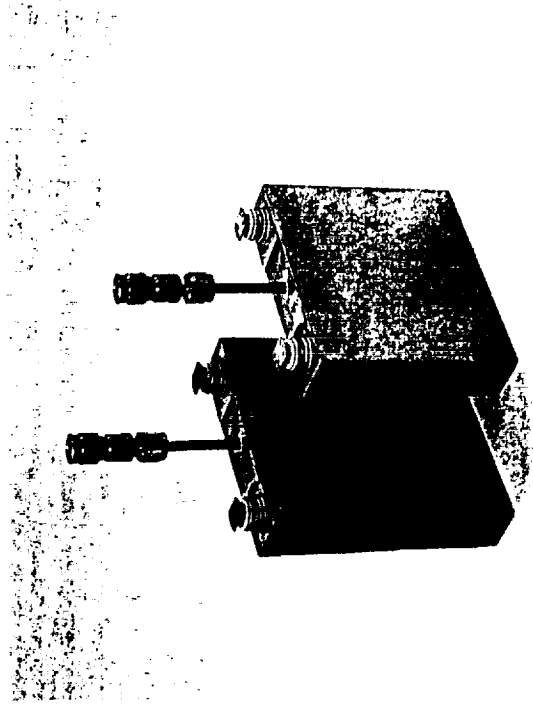
SUMMARY

LEO: FEASIBLE & SUITABLE

GEO: NEED THE DURABILITY FOR OVERCHARGE
BECAUSE LONG-TERM CHARGE RETENTION IS REQUIRED

**AEROSPACE Ni-MH CELL DESIGN IS BASED ON
AEROSPACE Ni-Cd CELL TECHNOLOGY**

Ni-MH CELL DESIGN	(+)	(-)
ACTIVE MATERIAL	Ni(OH) ₂	MnNi ₂
PLATE AREA	80.0 × 104.4 mm	0.43 mm
PLATE THICKNESS	0.60 mm	—
SINTER POROSITY	85 %	—
LOADING LEVEL	2.4g/cc-void	—
NUMBER OF PLATES	16	17
ELECTRODES CAPACITY	38.6 Ah	75.2 Ah †
N/P RATIO	1.95	—
SEPARATOR ELECTROLYTE	NYLON 31%KOH	—
CELL DIMENSION (case)	95.0H × 106.9W × 25.2T mm	—
CELL WEIGHT	840 g	—
CELL CAPACITY	35.5 Ah	—
ENERGY DENSITY (Actual)	50.7 Wh/kg	—
REFERENCE (35Ah SPACE Ni-Cd CELL)		
CELL DIMENSION (case)	115.2H × 106.9W × 25.2T mm	—
CELL WEIGHT	1040 g	—
CELL CAPACITY	38.6 Ah	—
ENERGY DENSITY (Actual)	44.5 Wh/kg	—



EXTERNAL VIEW OF THE Ni-MH CELL
35 Ah CLASS Ni-MH CELL (RIGHT)
AND 35 Ah Ni-Cd CELL (LEFT)
(A fill-tube is attached to both cells)

* The capacity of MH electrode is estimated that specific energy of hydrogen storage metal is 290mAh/g.



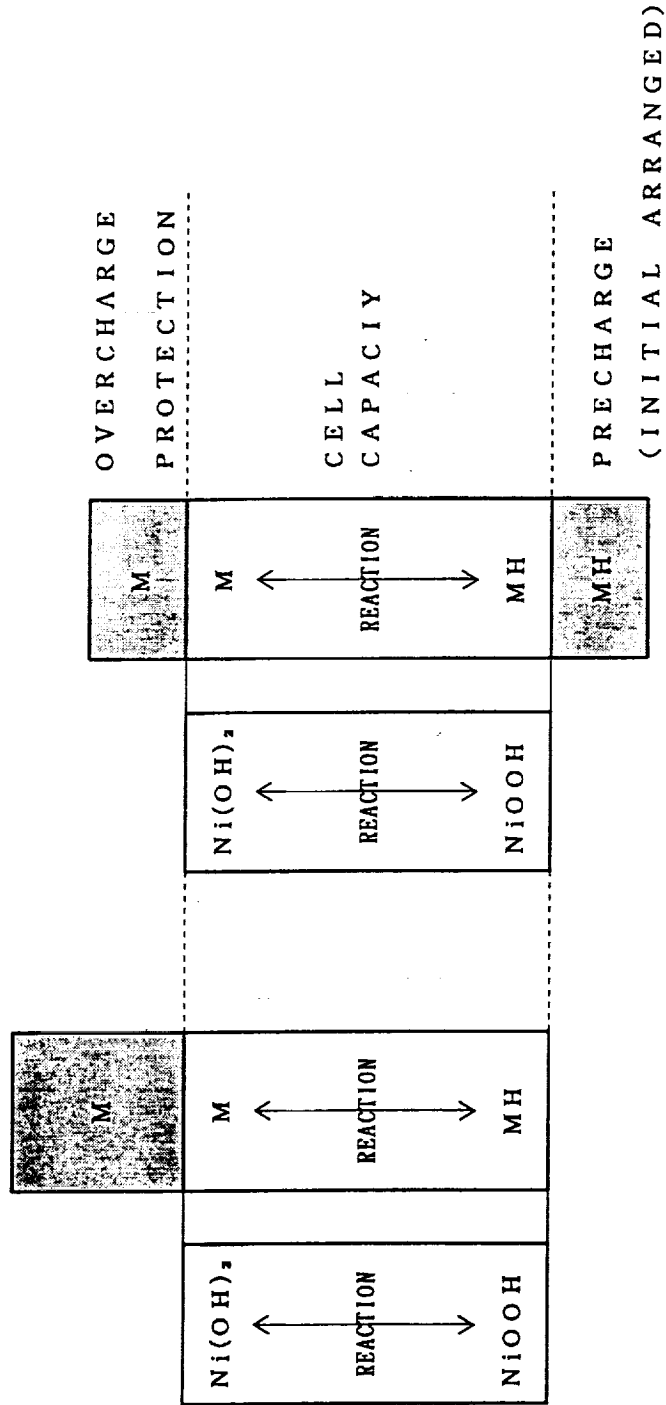
ACTIVATION PROCEDURES

AS ACTIVATION IN MANUFACTURE STEP,
TWO PROCEDURES ARE APPLIED
TO EVALUATE THE EFFECT OF ACTIVATIONS
AND RESULTED DIFFERENCE IN THE AMOUNT OF
OVERCHARGE PROTECTION AND PRECHARGE
ON CELL PERFORMANCE

BBM-A (5 CELLS) : CAPACITY-STABILIZING CYCLE
AFTER ELECTROLYTE FILLED

BBM-B (5 CELLS) : PRECHARGE ARRANGEMENT OF MH ELECTRODE
PRIOR TO STABILIZING CYCLE

CAPACITY SCHEMATICS OF Ni-MH CELLS



BBM-A

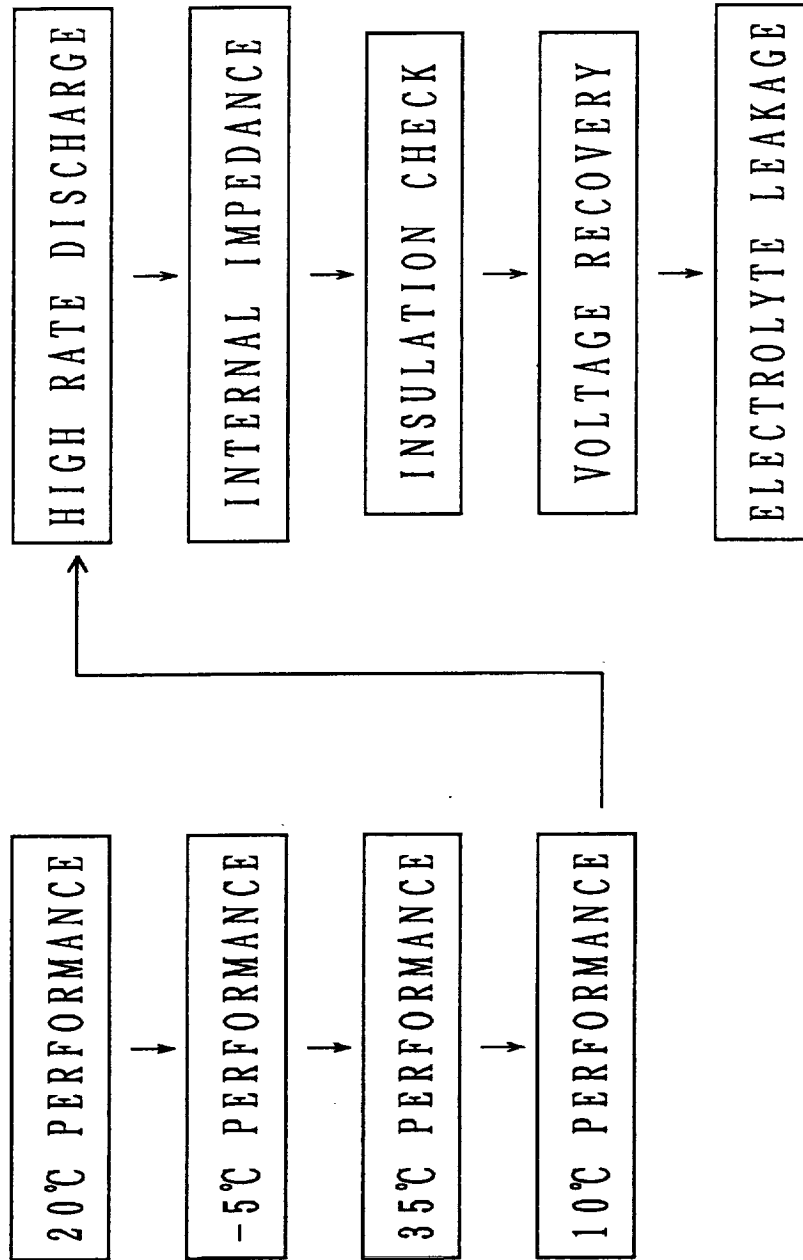
BBM-B



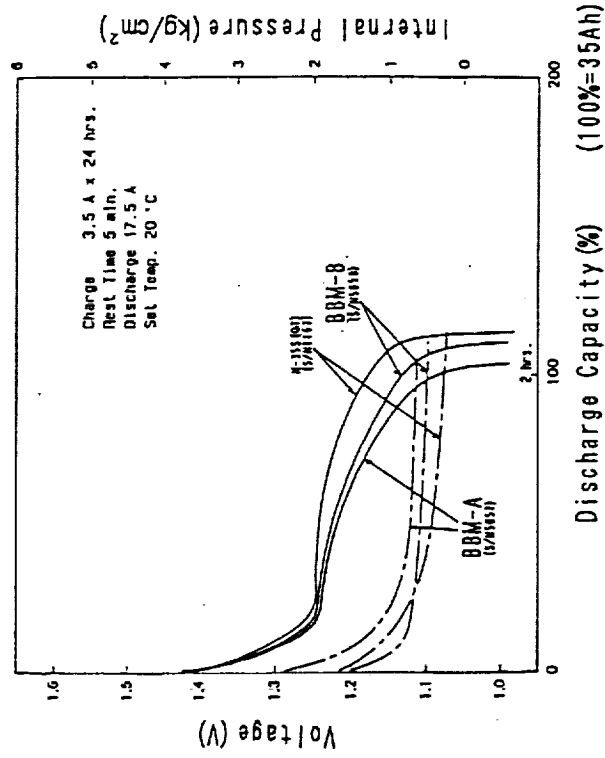
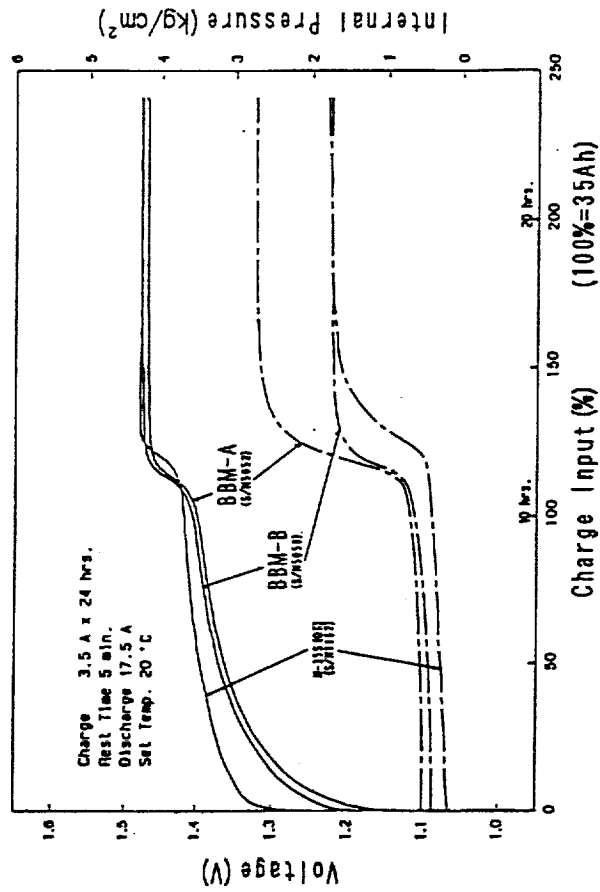
REPRESENTS EXCESS OF HYDROGEN ABSORBING CAPACITY



INITIAL EVALUATION TEST PROCEDURE



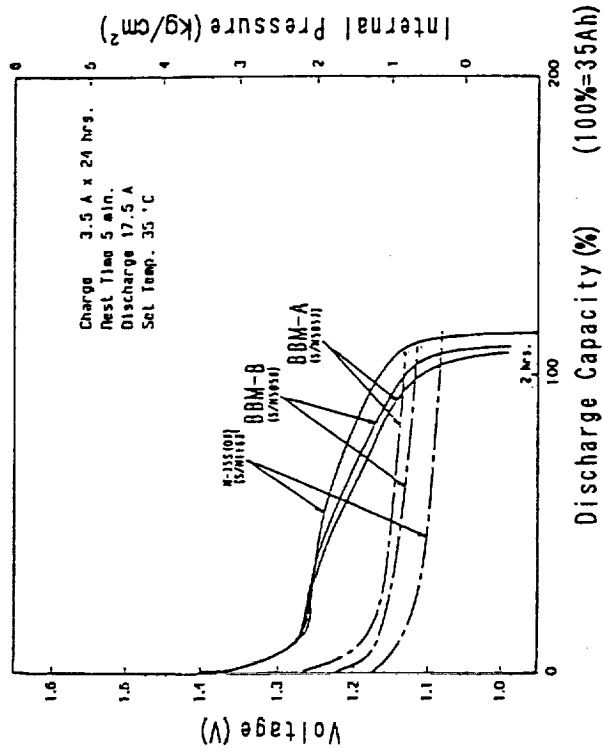
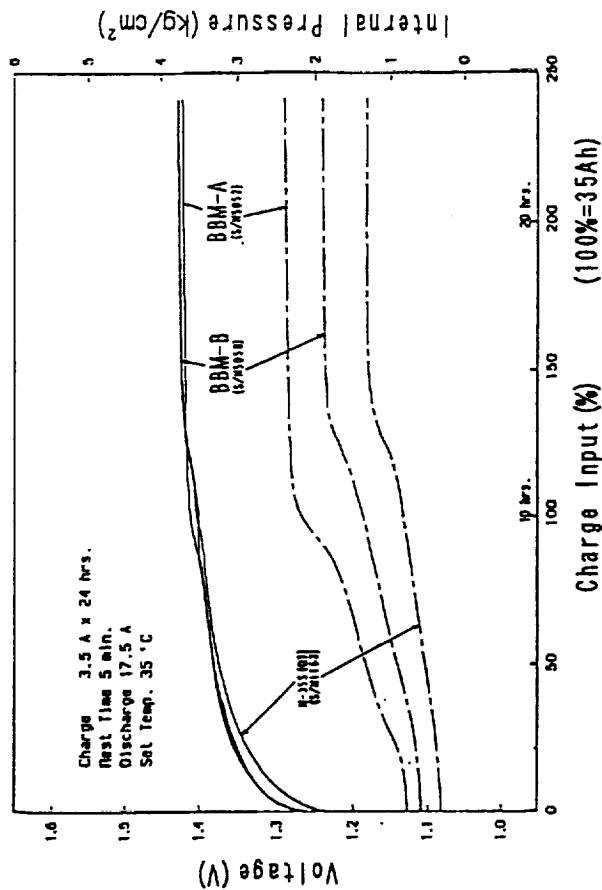
INITIAL CHARACTERISTICS OF THE Ni-MH CELLS AT 20°C



- DISCHARGE CAPACITY IS OVER THE DESIGN CAPACITY 35.5 Ah
- EOCP OF BBM-B IS LOWER THAN BBM-A
- DISCHARGE CAPACITY OF BBM-B IS LARGER THAN BBM-A
- THE RATE OF VOLTAGE RISE/DOWN AS CHARGE/DISCHARGE IS LARGE IN Ni-MH CELL

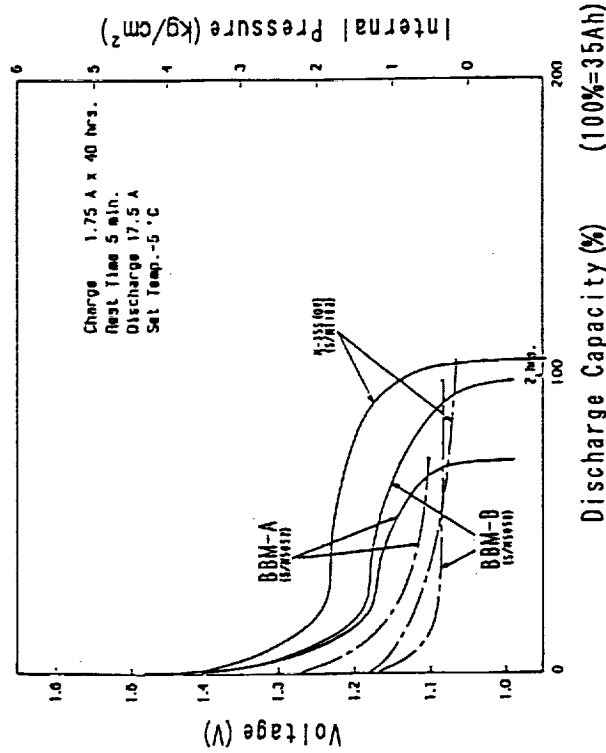
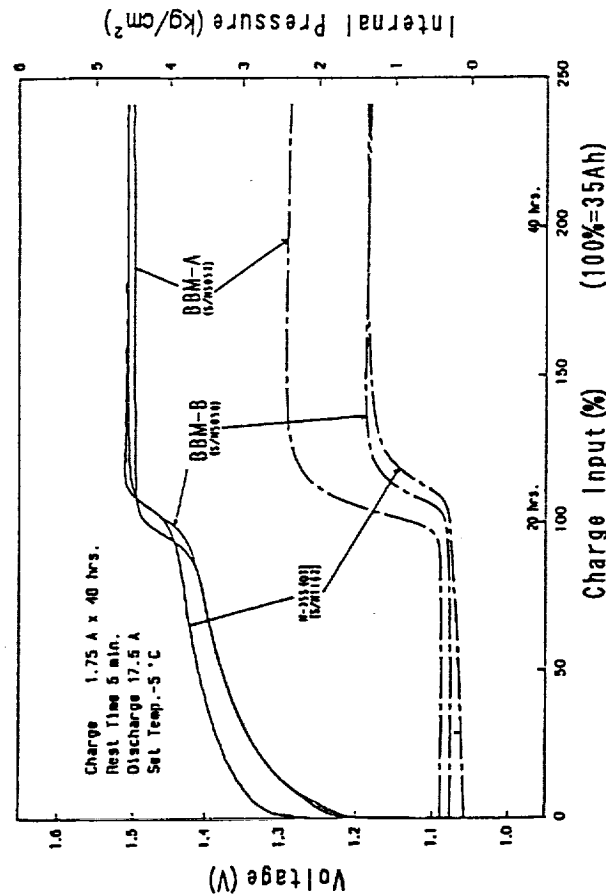


INITIAL CHARACTERISTICS OF THE NI-MH CELLS AT 35°C



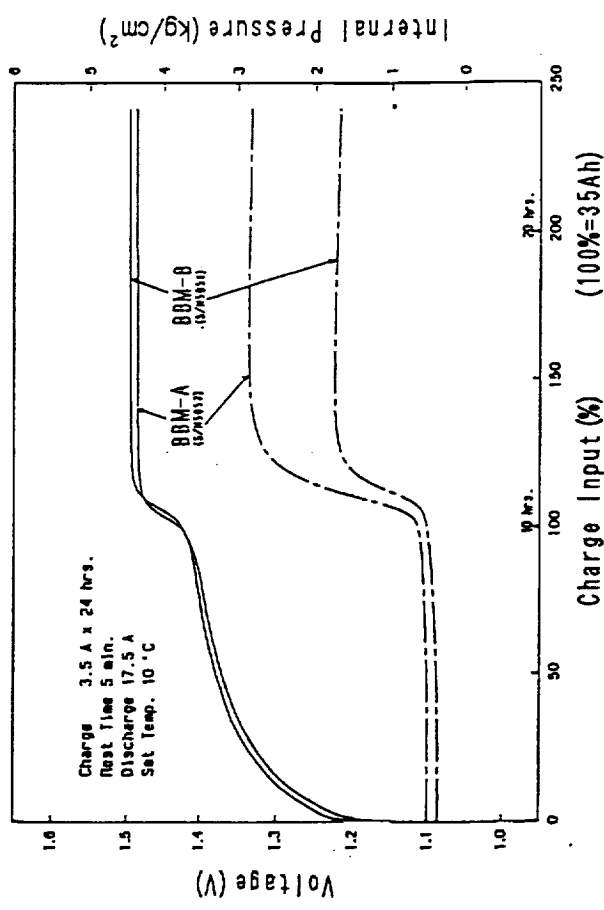
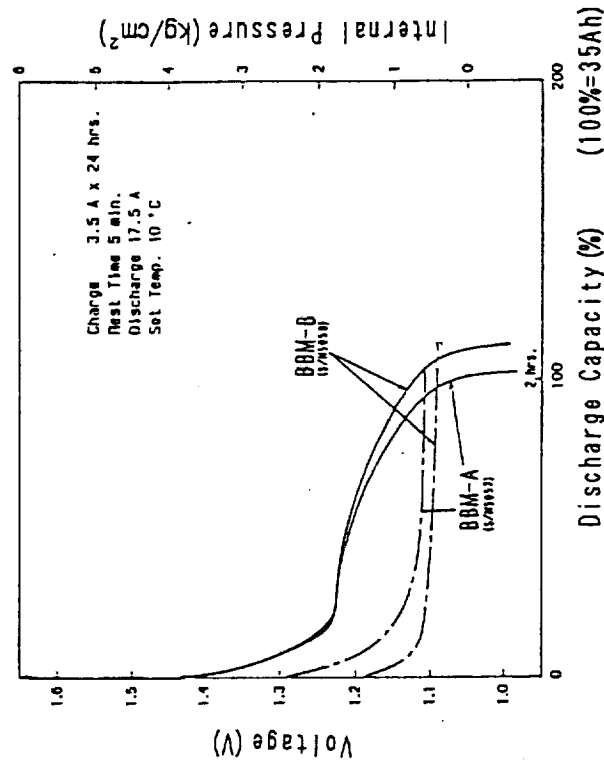
- CHARGE VOLTAGE OF NI-MH CELL IS SLIGHTLY HIGHER THAN NI-Cd
- CHARGE EFFICIENCY OF NI-MH CELL IS LOWER THAN NI-Cd

INITIAL CHARACTERISTICS OF THE Ni-MH CELLS AT -5°C



- DISCHARGE VOLTAGE IS ABOUT 50mV LOWER THAN Ni-Cd
- DISCHARGE CAPACITY IS LOWER THAN THE DESIGN CAPACITY 35.5 Ah
- THE CAPACITY OF BBM-B IS ABOUT 10Ah LARGER THAN BBM-A

NASDA NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN INITIAL CHARACTERISTICS OF THE Ni-MH CELLS AT 10°C



CHARGE & DISCHARGE CHARACTERISTICS ARE SIMILAR TO THE CHARACTERISTICS AT 20°C



INITIAL CHARACTERISTICS OF THE Ni-MH CELLS

THE DIFFERENCE BETWEEN BBM-A AND BBM-B

INITIAL CHARACTERISTICS		TEMPERATURE
EOCP	BBM-B LOWER THAN BBM-A	ALL TEMP.
CAPACITY	BBM-B SLIGHTLY LARGER THAN BBM-A	10, 20, 35°C
	BBM-B ABOUT 10Ah LARGER THAN BBM-A	-5°C

THE CHARACTERISTICS ARE DERIVED FROM PRECHARGE

INITIAL CHARACTERISTICS OF THE Ni-MH CELLS

THE COMPARISON WITH Ni-Cd CELL

TEMPERATURE	INITIAL CHARACTERISTICS
ALL TEMP.	THE RATE OF VOLTAGE RISE/DOWN AS CHARGE/DISCHARGE IS LARGE
35°C	CHARGE EFFICIENCY IS LOWER THAN Ni-Cd *)
-5°C	DISCHARGE VOLTAGE ABOUT 50mV LOWER THAN Ni-Cd *)

* THE CHARACTERISTICS ARE DERIVED FROM PROPERTY THAT HYDROGEN STORAGE METAL IS ACTIVATED TO RELEASE HYDROGEN AT HIGH TEMPERATURE, AND DEACTIVATED AT LOW TEMPERATURE



LIFE EVALUATION OF 35Ah CLASS Ni-MH CELLS

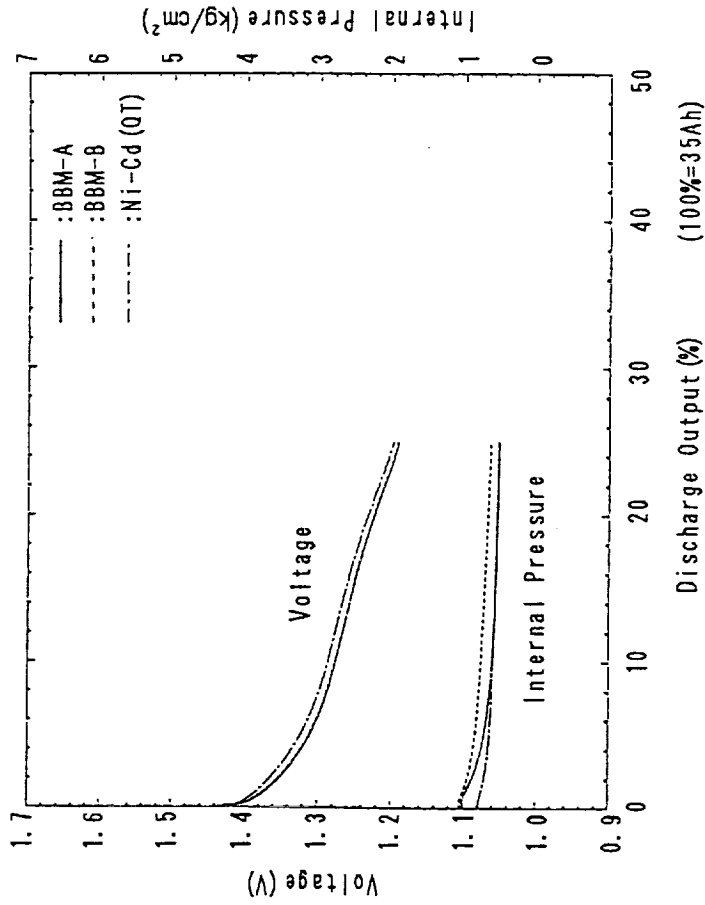
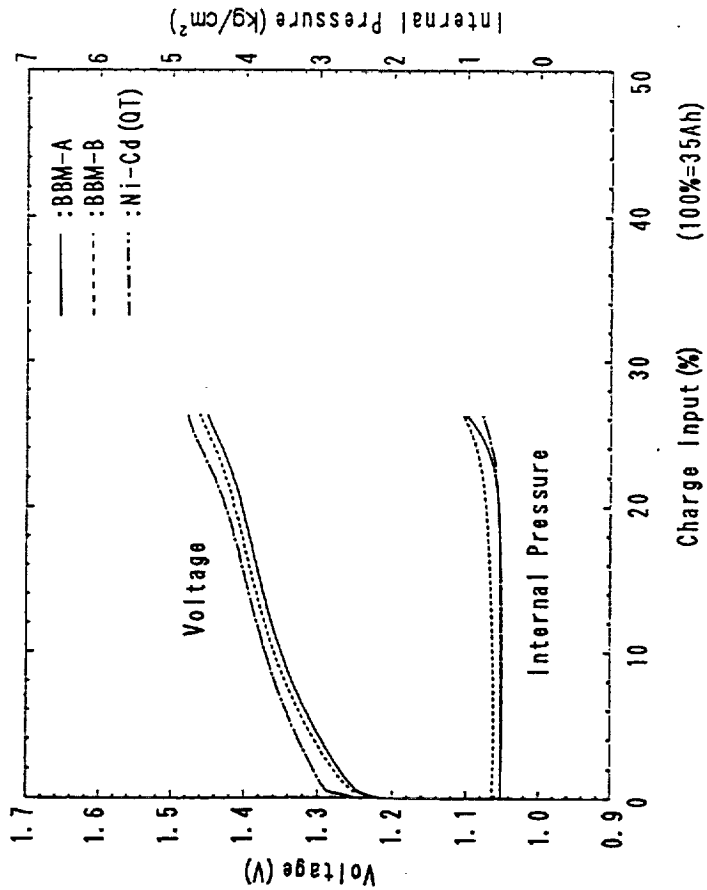
TEST CONDITIONS OF LIFE TEST

CONDITION	TEST TYPE	25%DOD-LEO	40%DOD-LEO
CELL		3 BBM-A + 3 BBM-B	2 BBM-A + 2 BBM-B
CHARGE		0.3C, 52.5 min	0.48C, 52.5 min
DISCHARGE		0.5C, 30 min	0.8C, 30 min
DOD		25 %	40 %
CHARGE RETURN		105 %	
CELL TEMP.		20°C (MAINTAINED BY CHAMBER)	
CAPACITY CHECK		RESIDUAL CAPACITY *1	
		FULL-CHARGED CAPACITY *2	
1,000 CYCLES, 3,000 CYCLES AND THEN ABOUT EVERY 5,000 CYCLES			

(C = 35 A)

- * 1 : Residual Capacity is obtained by 0.5C discharge to 1 Volt after LEO cycling charge.
- * 2 : Full-charged Capacity is obtained by 0.5C discharge to 1 Volt after full-charging with 0.1C for 16hours.

CHARGE & DISCHARGE CHARACTERISTICS IN CYCLING
AT NEARLY 3000 CYCLES

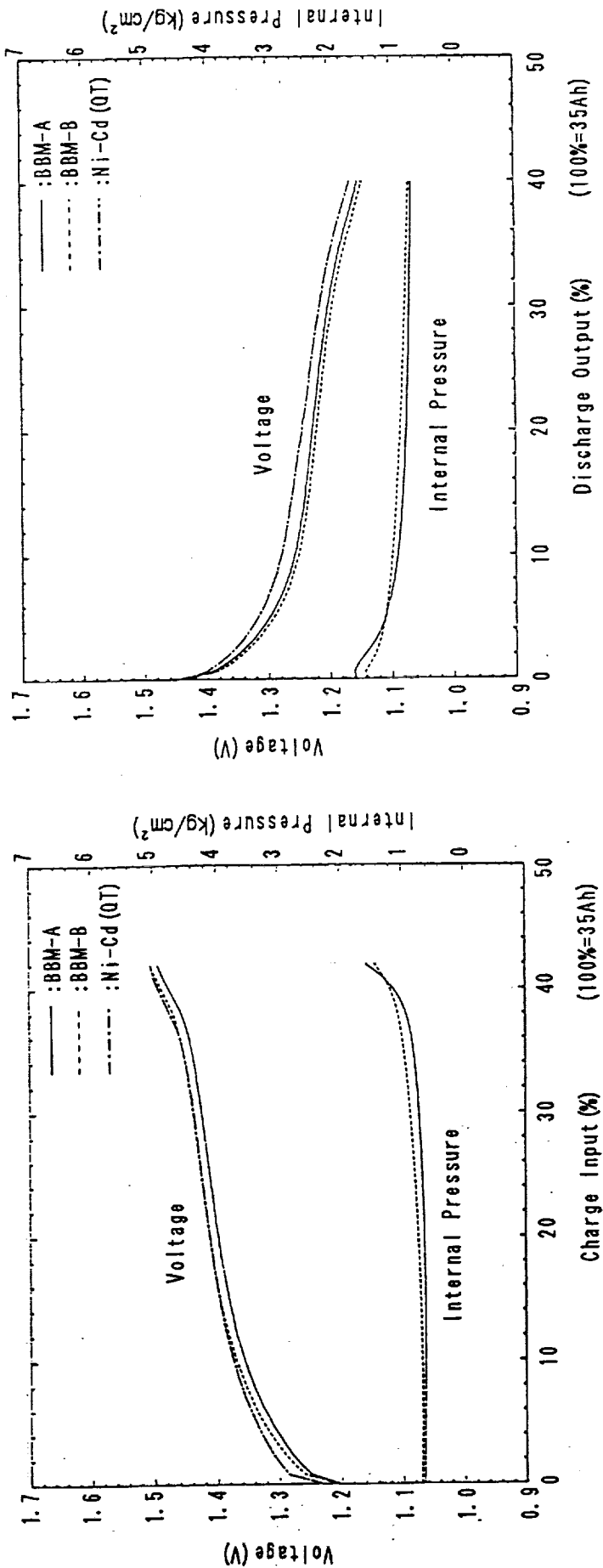


TEST CONDITION / CHARGE : 0.3C FOR 52.5 MINUTES
 DISCHARGE : 0.5C FOR 30 MINUTES (DOD: 25%)
 CELL TEMP: 20°C



40%DOD-LEO TEST OF 35Ah CLASS Ni-MH CELLS

CHARGE & DISCHARGE CHARACTERISTICS IN CYCLING
AT NEARLY 3000 CYCLES

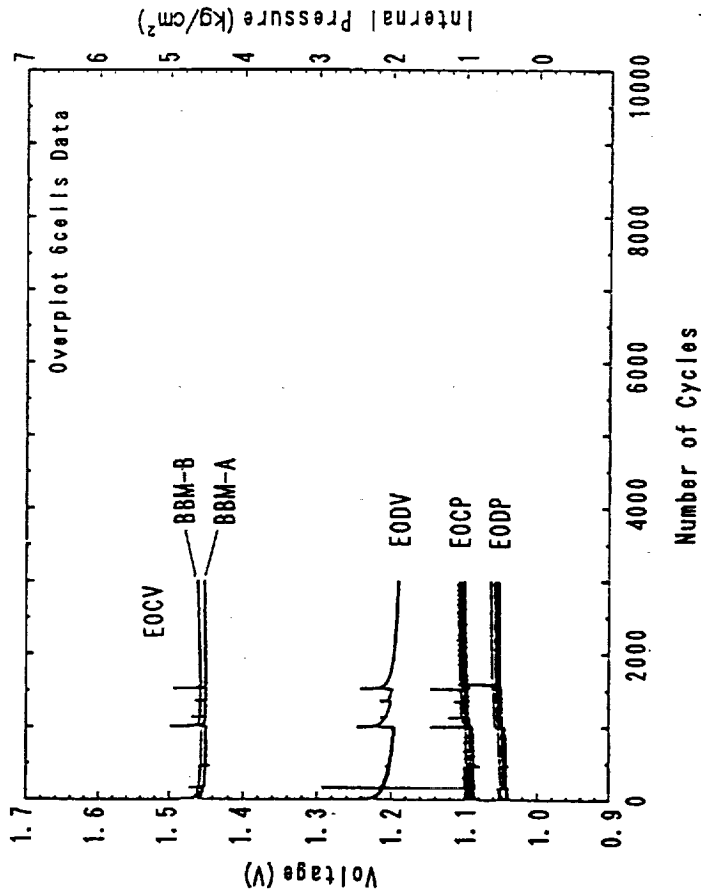


TEST CONDITION / CHARGE : 0.48C FOR 52.5 MINUTES
DISCHARGE: 0.8C FOR 30 MINUTES (DOD: 25%)
CELL TEMP: 20°C

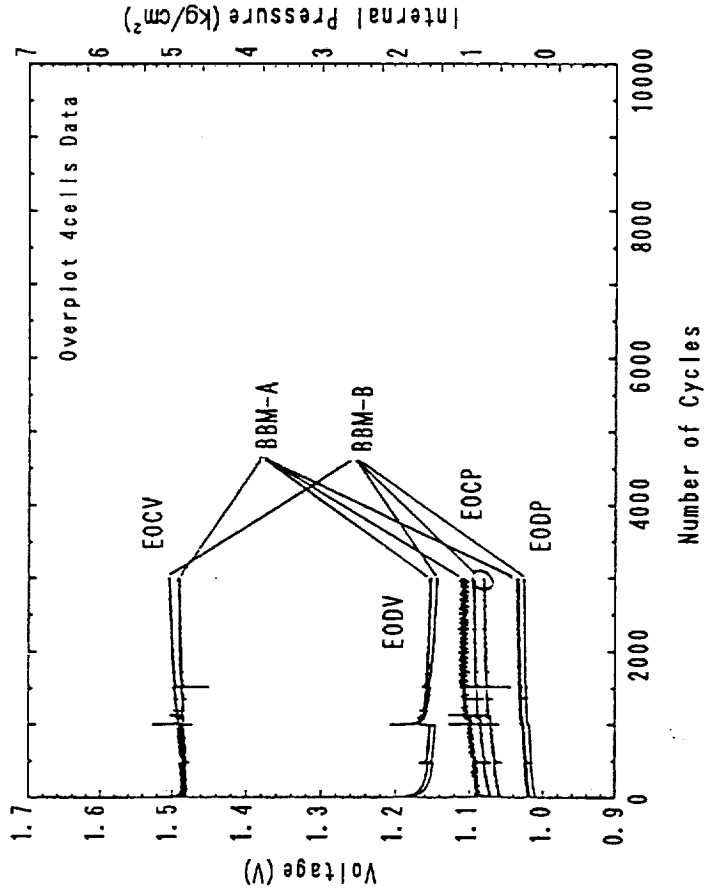


TREND OF EOCV, EODV, EOCV & EODP ON LEO TEST

25%DOD



40%DOD



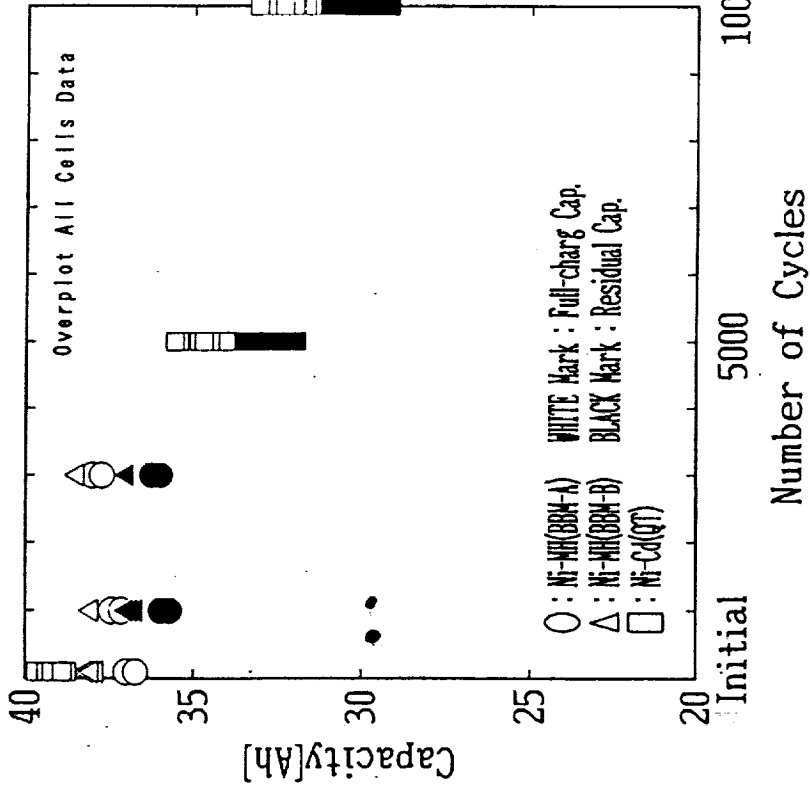
BOTH OF LEO TESTS ARE OVER 3,000 CYCLES SO FAR NO FAILURES
EOCV OF BBM-B ARE GRADUALLY INCREASING ON 40%DOD-LEO CYCLE TEST



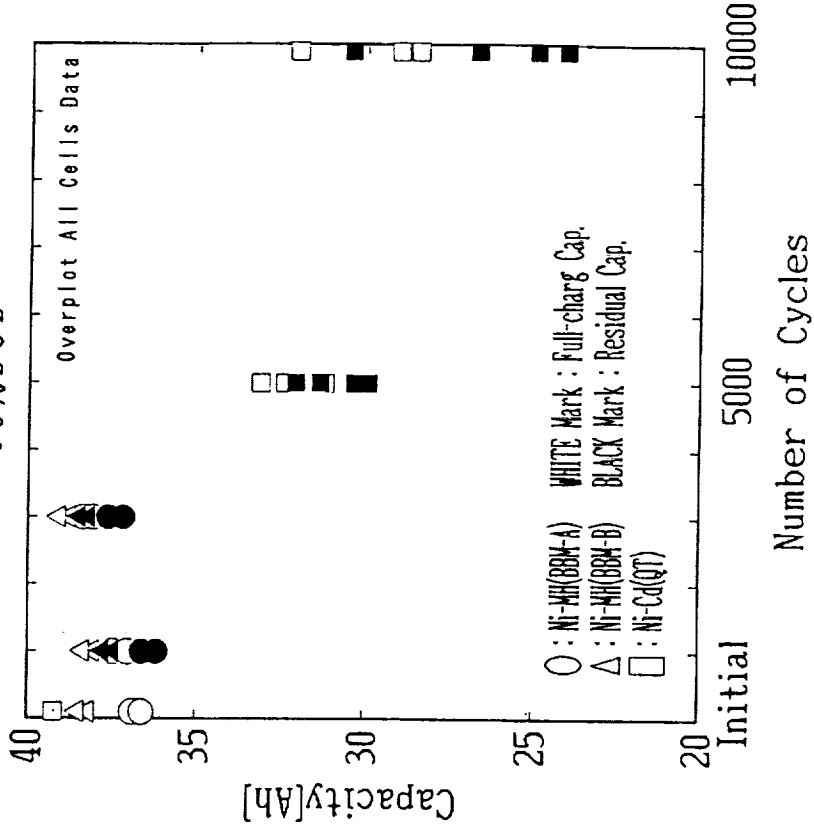
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TREND OF CAPACITIES ON LEO TEST

25%DOD



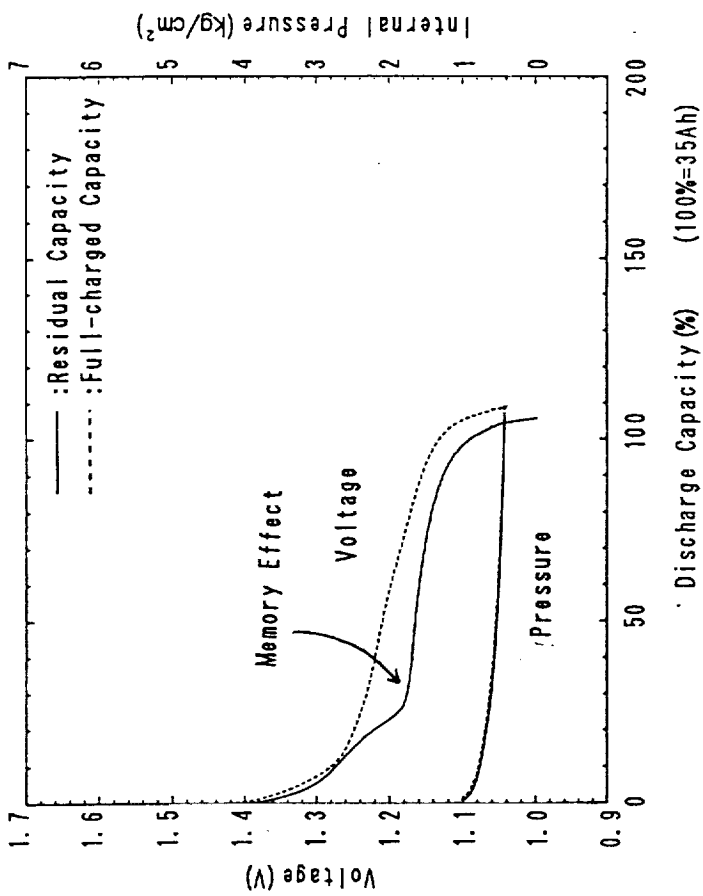
40%DOD



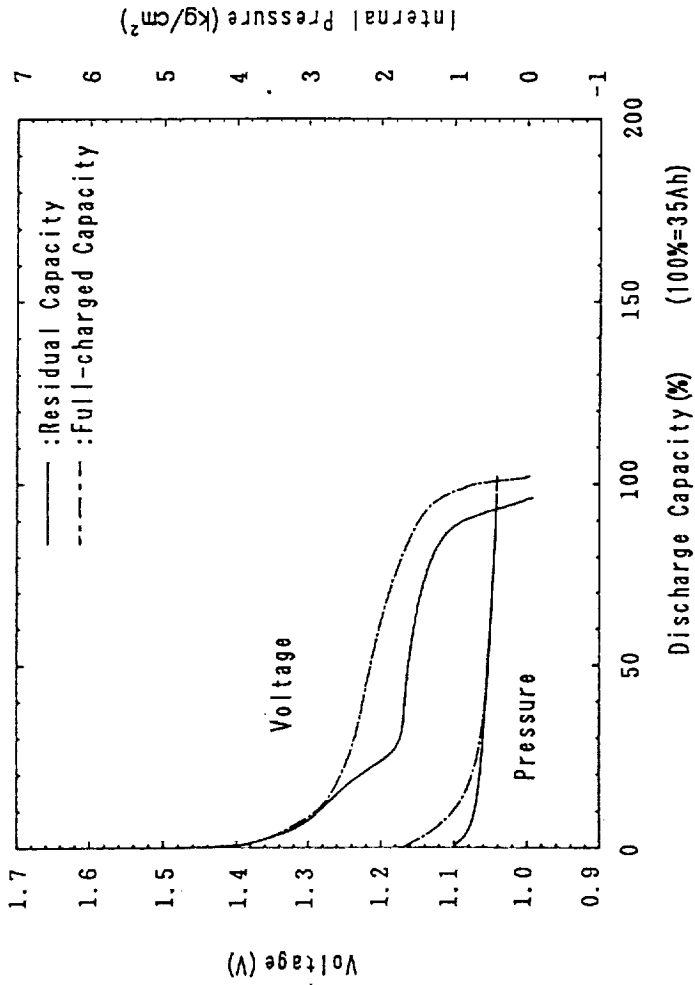
THE NI-MH CELLS HAVE GOOD PERFORMANCE ABOUT CAPACITY REMAINING ESPECIALLY, AS SIMILAR TO COMMERCIAL NI-MH CELLS

DISCHARGE CHARACTERISTICS IN CAPACITY CHECK ON 25%DOD

Ni-MH (BBM-B) AT 3000 CYCLES



Ni-CD (QT) AT 5000 CYCLES



DIFFERENCE OF DISCHARGE VOLTAGE DERIVED FROM
THE MEMORY EFFECT IS 50mV THAT IS SIMILAR TO Ni-Cd



LIFE EVALUATION OF 35Ah CLASS Ni-MH CELLS

THE DIFFERENCE BETWEEN BBM-A AND BBM-B

CHARACTERISTICS		D O D
CHARGE VOLTAGE	BBM-A < BBM-B	20, 40%
CHARGE PRESSURE RISE AT OVERCHARGE	BBM-A > BBM-B	20, 40%
INCREASE OF EOCV	BBM-A < BBM-B	40%



DEVELOPMENT OF NI-MH CELL FOR SPACE USE

SUMMARY

- TWO ACTIVATION PROCEDURES ARE APPLIED TO EVALUATE THE EFFECT OF DIFFERENCE IN THE AMOUNT OF OVERCHARGE PROTECTION & PRECHARGE
- SPECIFIC ENERGY OF THE NI-MH CELL IS NEARLY ACCOMPLISHED 50Wh/kg
- INITIAL CHARACTERISTICS INDICATE THE EFFECT DERIVED FROM PRECHARGE
- 35Ah CLASS NI-MH CELLS HAVE GOOD PERFORMANCE FOR LEO CYCLE OF 25% & 40% DOD UP TO 3000 CYCLES AS SIMILAR TO COMMERCIAL CELLS
- THE EFFECT OF THE DIFFERENCE IN THE AMOUNT OF OVERCHARGE PROTECTION WILL APPEAR IN LIFE TEST



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CONCLUSION

EVALUATION OF COMMERCIAL Ni-MH CELL

- Ni-MH CELL IS SUITABLE TO LEO APPLICATION
- ONE OF THE Ni-MH FAILURE MODE IS DEGRADATION OF MH ELECTRODE SUCH AS OXIDATION, CAUSING LOSS OF OVERCHARGE PROTECTION

DEVELOPMENT OF Ni-MH CELL FOR SPACE USE

- WE MANUFACTURED 35Ah CLASS FLIGHT-TYPE Ni-MH CELL BASED ON THE COMMERCIAL CELL AND AEROSPACE Ni-Cd CELL TECHNOLOGY
- WE CONTINUE TO EVALUATE THE EFFECT OF THE DIFFERENCE IN THE AMOUNT OF OVERCHARGE PROTECTION ON LIFE PERFORMANCE



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PLAN OF Ni-MH CELLS FOR SPACE USE

NOW WE ARE DESIGNING OF 10 TO 20Ah FOR SMALL SATELLITE

IT IS PLANNED TO APPLY THE RESULTS OF R&D ON Ni-MH CELLS
FOR OPTICAL INTER-SATELLITE COMMUNICATION ENGINEERING
TEST SATELLITE(OICETS) TO BE LAUNCHED IN 1998

