N94-28130

Pg 34

DEVELOPMENT of NICKEL-METAL HYDRIDE CELL

An Update

1993 NASA Aerospace Battery Workshop

November 16~18, 1993

S. Kuwajima, H. Kusawake & K. Nakatani,* Y. Yano*

National Space Development Agency of Japan

*SANYO Electric Co., Ltd.

NASDA NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN

DEVELOPMENT OF NICKEL METAL-HYDRIDE CELL

OVERVIEW

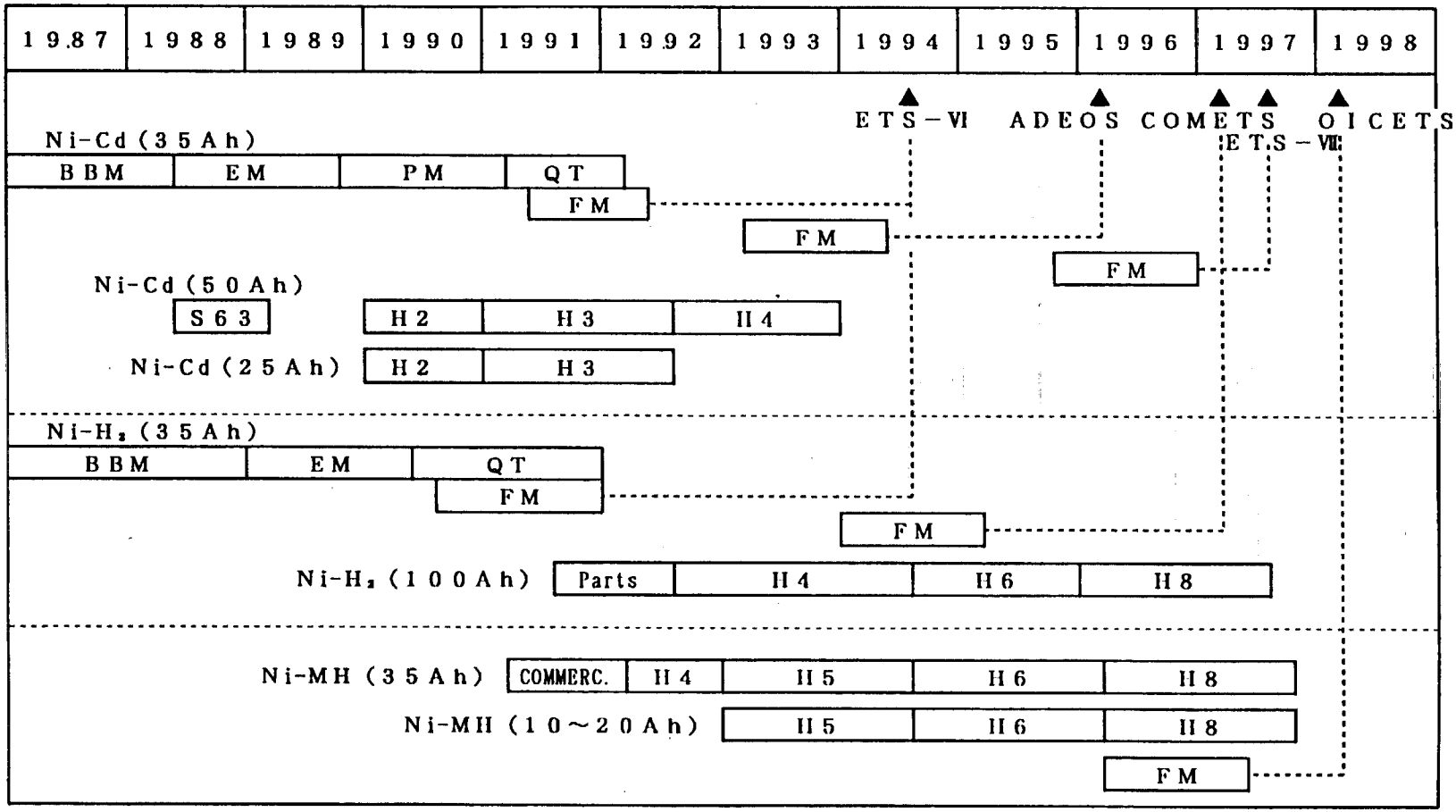
NASDA BATTERY DEVELOPMENT SCHEDULE

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

NASDA NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN

SCHEDULE OF BATTERY DEVELOPMENT IN NASDA

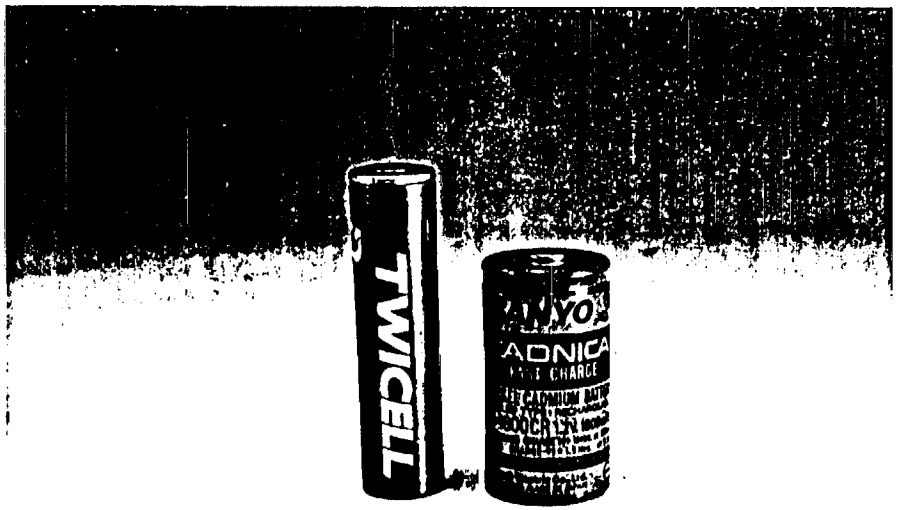


NASDA NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN

EVALUATION OF COMMERCIAL Ni-MH CELL

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

NASDA NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN

EVALUATION OF COMMERCIAL Ni-MH CELLS

TEST CONDITIONS OF LIFE TEST

CONDITION \ TEST TYPE	GEO	LEO
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、1.2hours	0.5C、30 min
DOD	60 %	25 %
CHARGE RETURN	150 %	105 %
TEMPERATURE	20℃ (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.

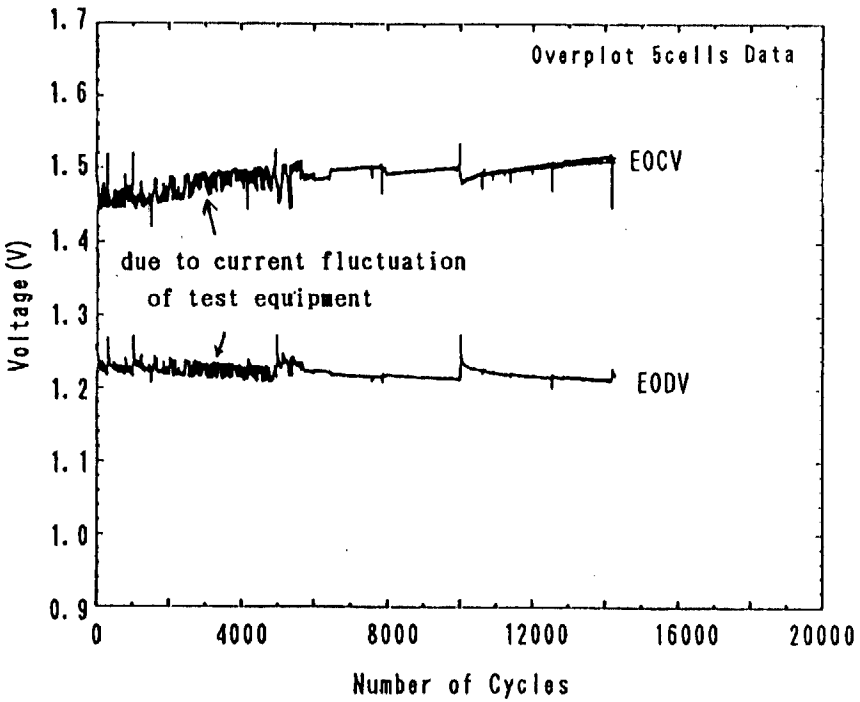
*2 : Residual Capacity is obtained by 0.5C discharge to 1 Volt after LEO cycling charge.

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

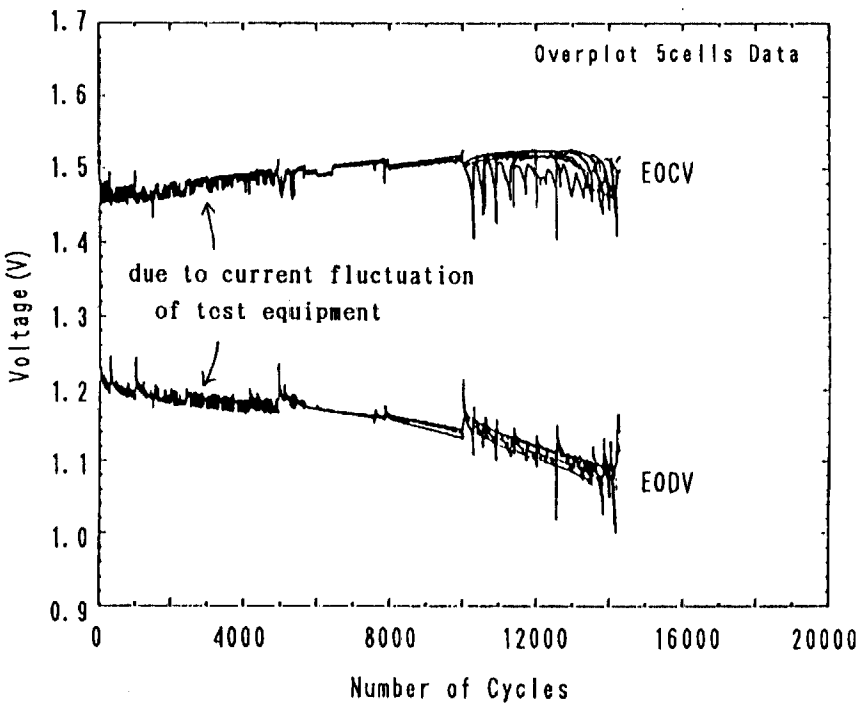
NASDA NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN

TREND OF EOCV & EODV ON LEO TEST (COMMERCIAL)

Ni-MH CELLS



Ni-Cd CELLS

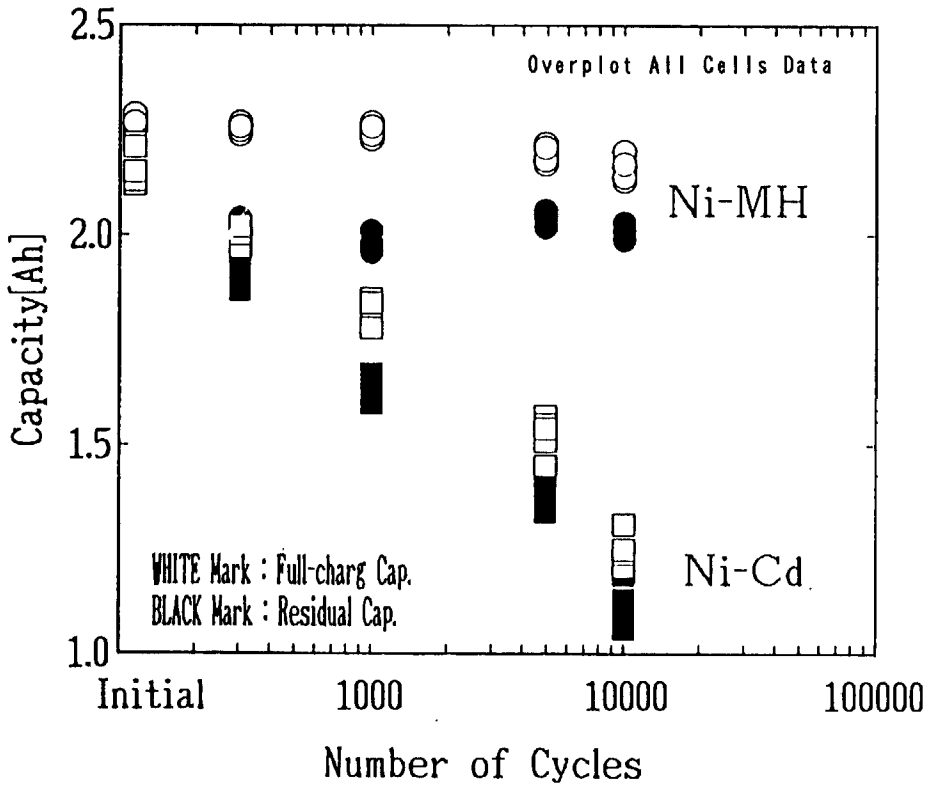


THE COMMERCIAL Ni-MH CELLS HAVE GOOD PERFORMANCE WITH RESPECT TO STABILITY OF EOCV AND EODV

NASDA NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN

LEO TEST OF COMMERCIAL Ni-MH CELLS

TREND OF CAPACITIES

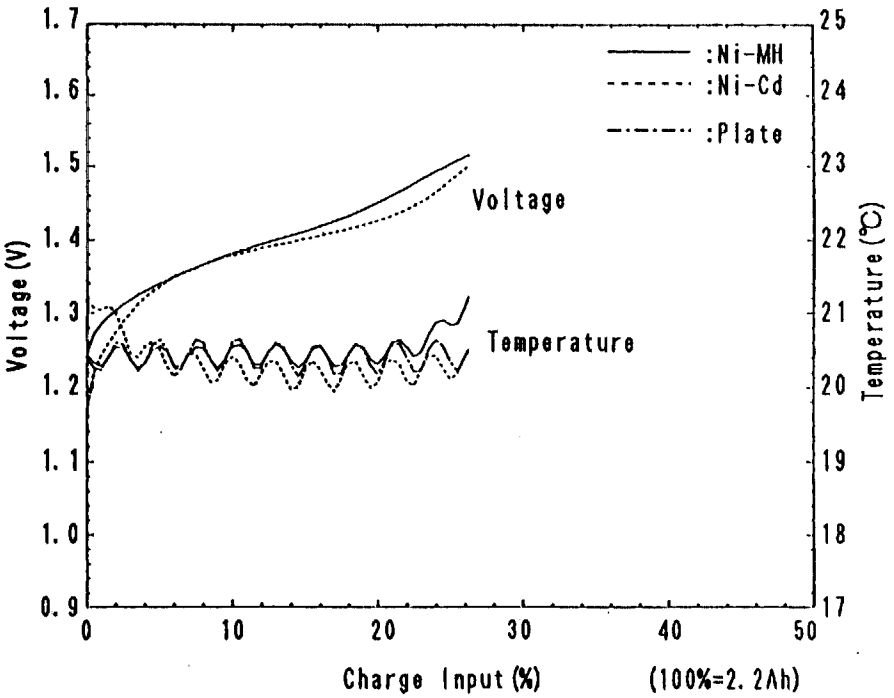


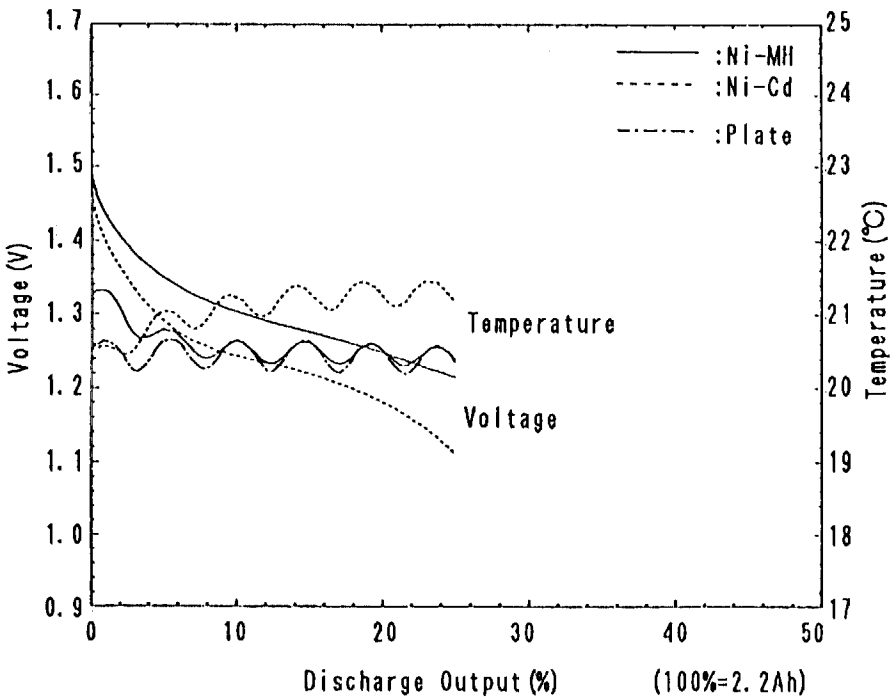
THE COMMERCIAL Ni-MH CELLS HAVE GOOD PERFORMANCE ABOUT CAPACITY REMAINING ESPECIALLY

NASDA NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN

LEO TEST OF COMMERCIAL Ni-MH CELLS

CHARGE & DISCHARGE CHARACTERISTICS IN CYCLING AT 14020 CYCLES



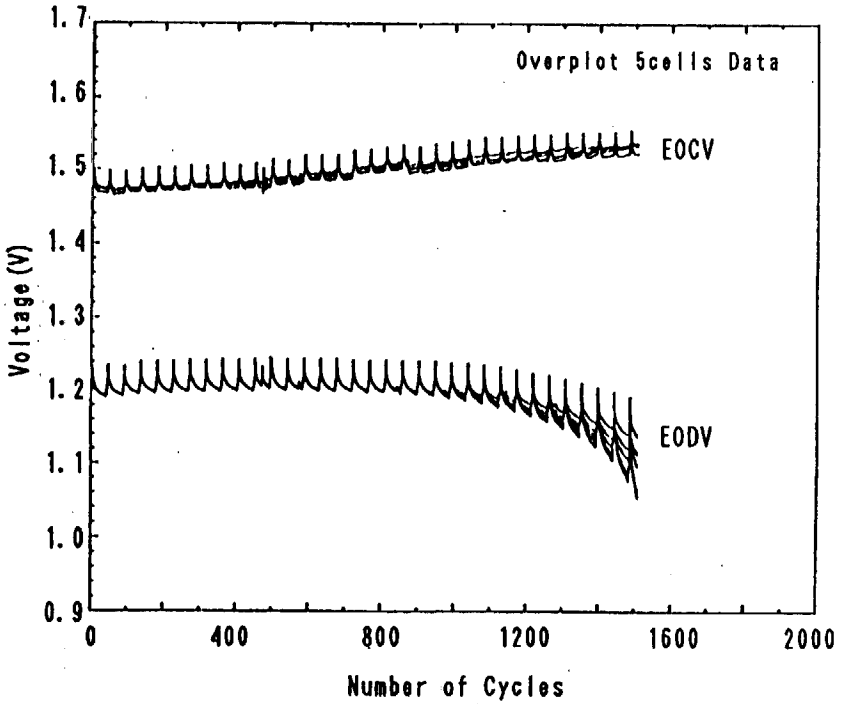


TEST CONDITION/ CHARGE : 0.3C FOR 52.5 MINUTES
DISCHARGE : 0.5C FOR 30 MINUTES (DOD : 25%)
PLATE TEMP : 20℃

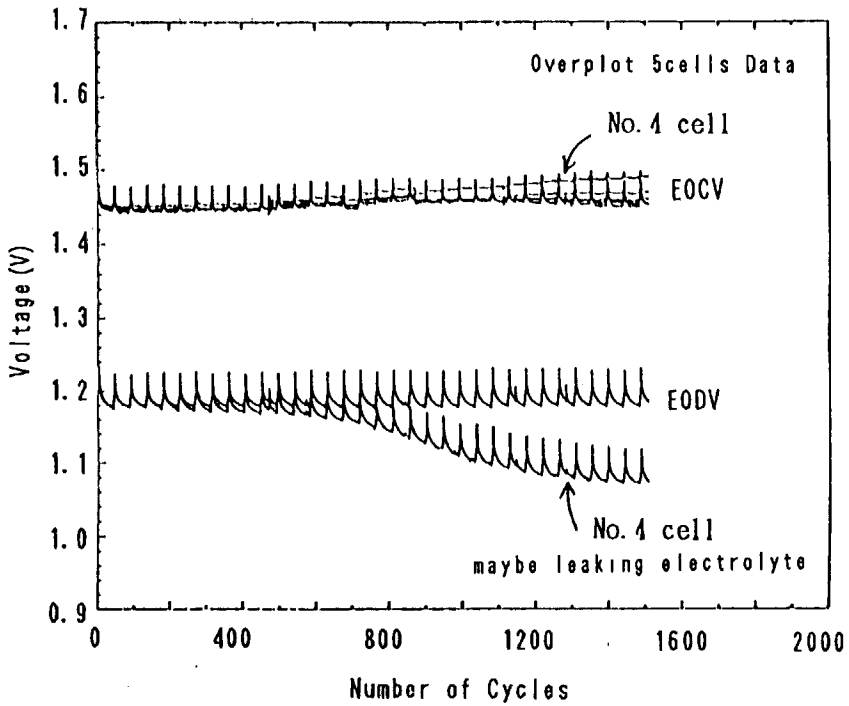
NASDA NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN

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

NASDA NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN

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

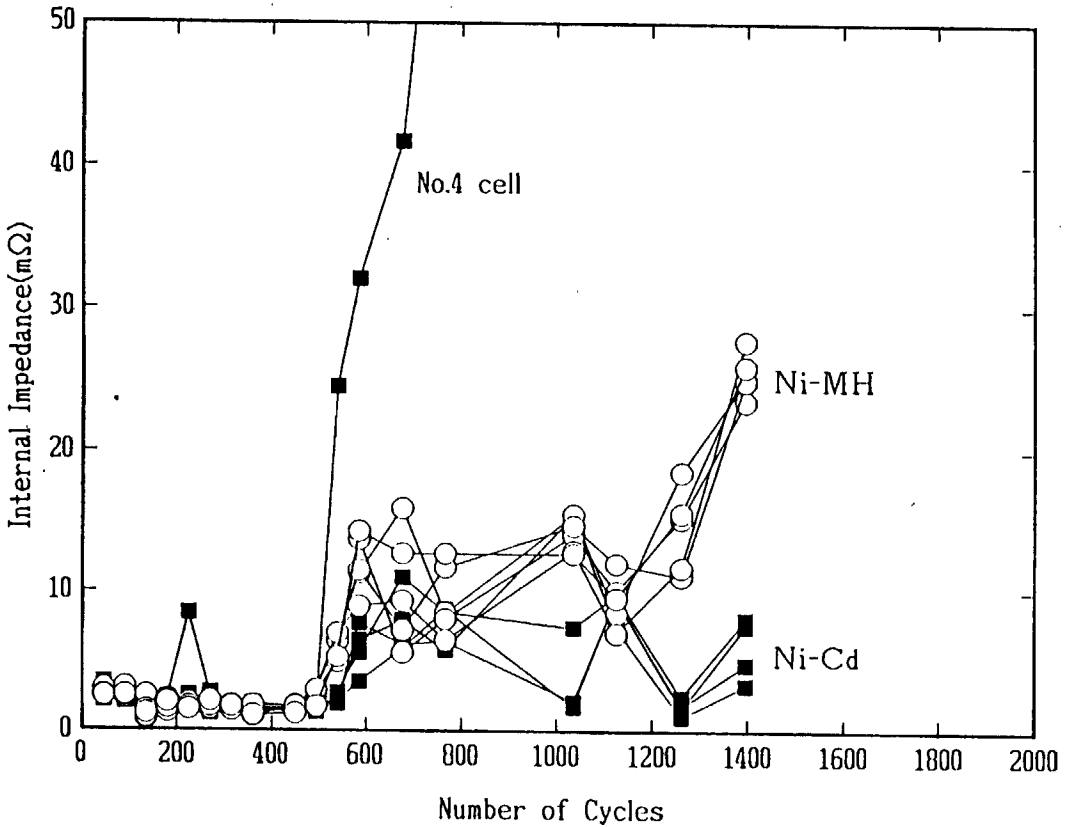
↓

DOWNWARD TREND OF EODV
(INTERNAL IMPEDANCE INCREASE)

NASDA NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN

GEO TEST OF COMMERCIAL Ni-MH CELLS

TREND OF INTERNAL IMPEDANCE @ 1kHz



INCREASE OF INTERNAL IMPEDANCE ALSO INDICATES LOSS OF ELECTROLYTE

NASDA NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN

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

NASDA NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN

EVALUATION OF COMMERCIAL Ni-MH CELLS

SUMMARY

LEO: FEASIBLE & SUITABLE

GEO: NEED THE DURABILITY FOR OVERCHARGE

BECAUSE LONG-TERM CHARGE RETENTION IS REQUIRED

NASDA NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN

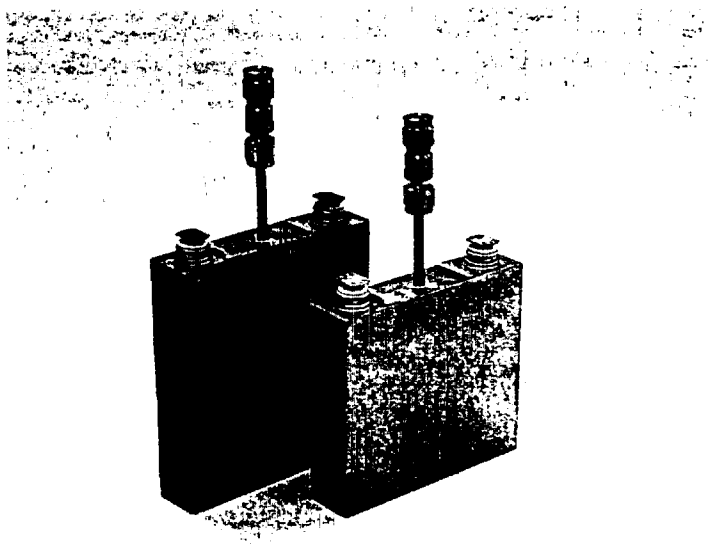
AEROSPACE Ni-MH CELL DESIGN

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

Ni-MH CELL DESIGN	(+)	(−)
ACTIVE MATERIAL	$Ni(OH)_2$	$MmNi_5$
PLATE AREA	80.0×104.4 mm	
PLATE THICKNESS	0.60 mm	0.43 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	NYLON	
ELECTROLYTE	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

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



EXTERNAL VIEW OF THE Ni-MH CELL

35Ah CLASS Ni-MH CELL (RIGHT) AND 35Ah Ni-Cd CELL (LEFT)

(A fill-tube is attached to both cells)

NASDA NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN

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

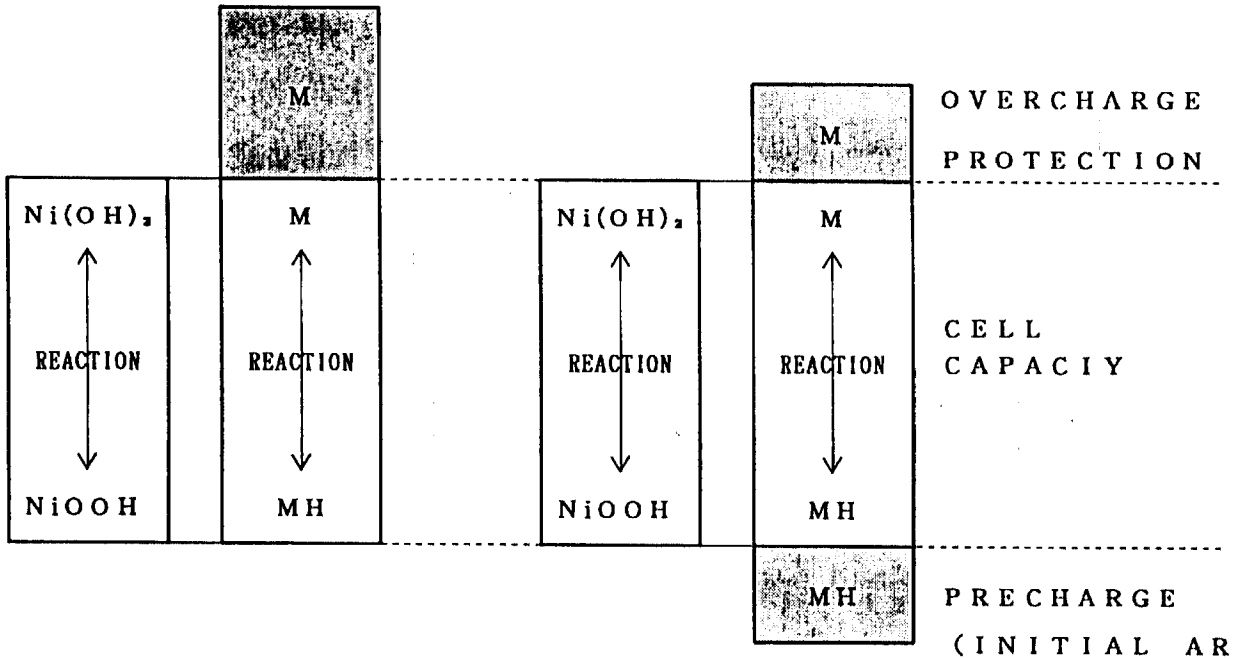
BBM-A (5CELLS) : CAPACITY-STABILIZING CYCLE
AFTER ELECTROLYTE FILLED

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

Q-8

NASDA NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN

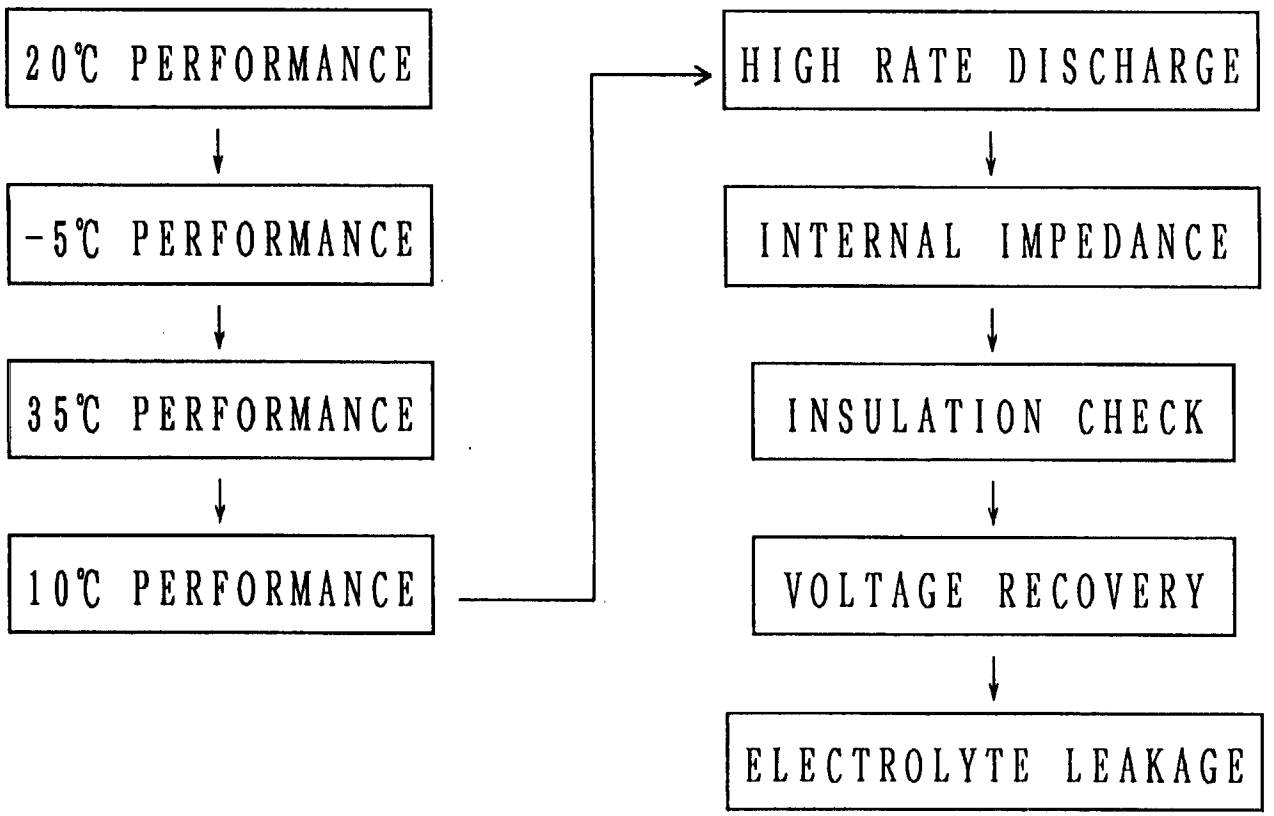
CAPACITY SCHEMATICS OF Ni-MH CELLS



REPRESENTS EXCESS OF HYDROGEN ABSORBING CAPACITY

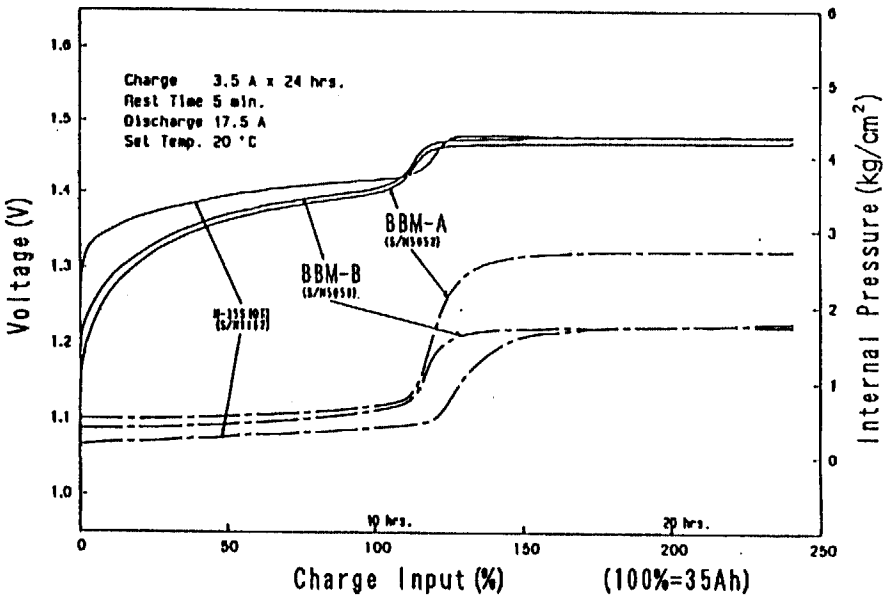
NASDA NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN

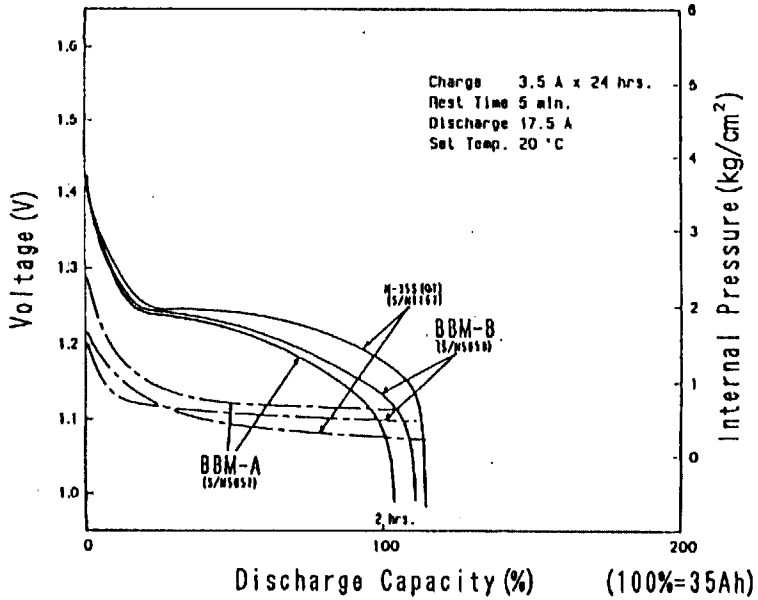
INITIAL EVALUATION TEST PROCEDURE



NASDA NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN

INITIAL CHARACTERISTICS OF THE Ni-MH CELLS AT 20℃

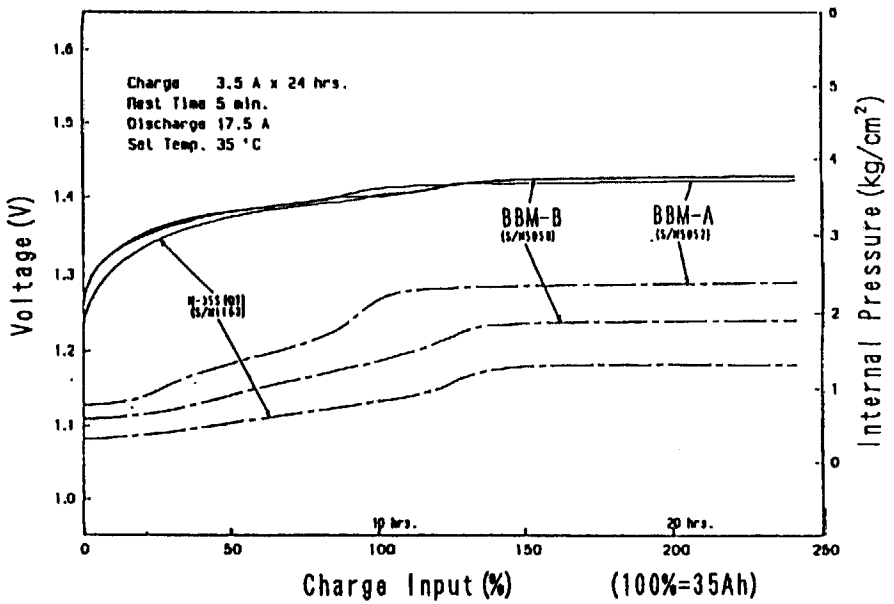


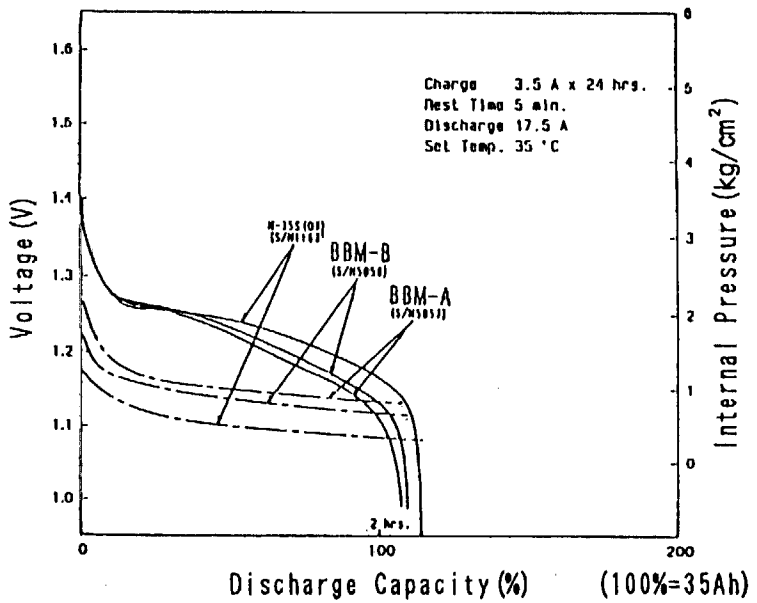


- DISCHARGE CAPACITY IS OVER THE DESIGN CAPACITY 35.5Ah
- EOCP OF BBM-B IS LOWER THAN BBM-A
- DISCHARGE CAPACITY OF BBM-B IS LARGER THAN BBM-A
- THE RATE OF VOLTAGE RISE/DOWN AS CHARGE/DISCHARGE IS LARGE IN Ni-MH CELL

NASDA NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN

INITIAL CHARACTERISTICS OF THE Ni-MH CELLS AT 35℃

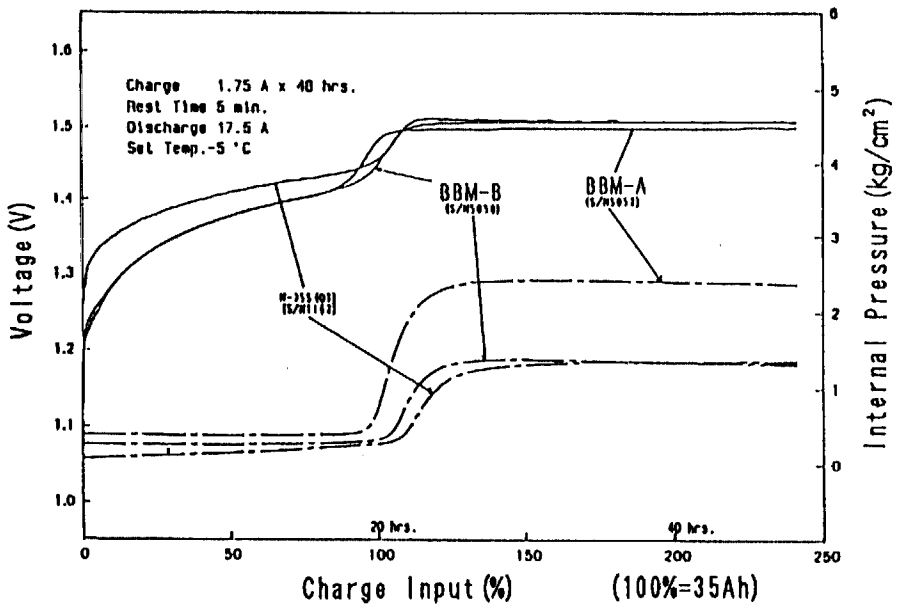


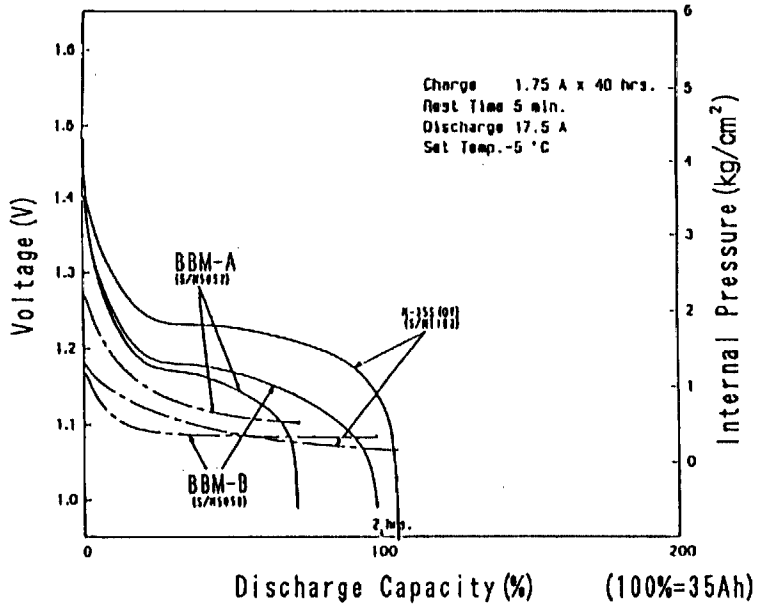


- CHARGE VOLTAGE OF Ni-MH CELL IS SLIGHTLY HIGHER THAN Ni-Cd
- CHARGE EFFICIENCY OF Ni-MH CELL IS LOWER THAN Ni-Cd

NASDA NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN

INITIAL CHARACTERISTICS OF THE Ni-MH CELLS AT -5℃

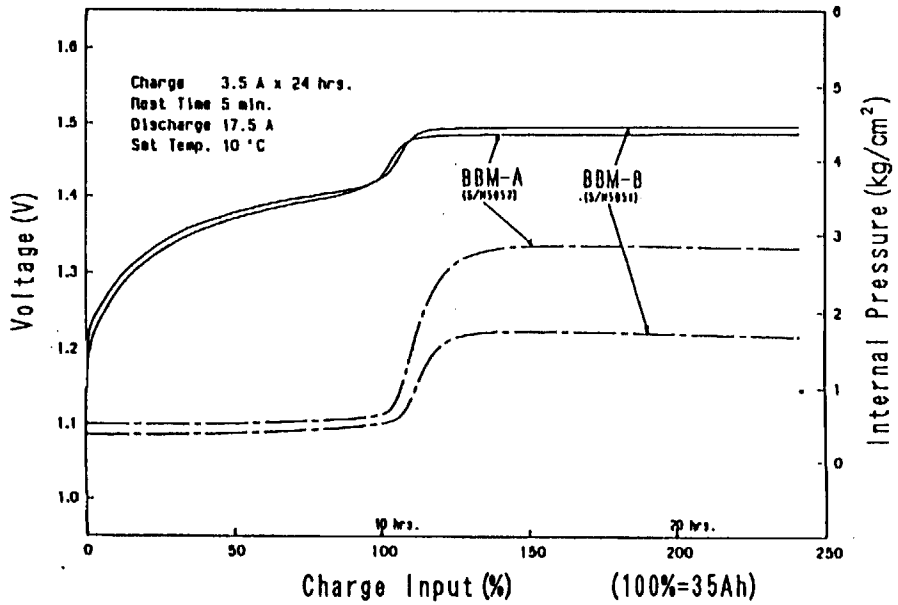


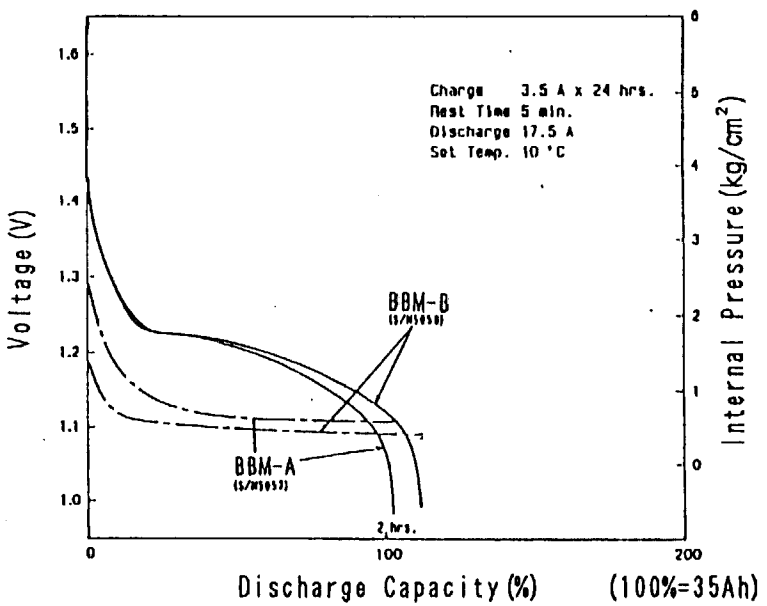


- DISCHARGE VOLTAGE IS ABOUT 50mV LOWER THAN Ni-Cd
- DISCHARGE CAPACITY IS LOWER THAN THE DESIGN CAPACITY 35.5Ah
- THE CAPACITY OF BBM-B IS ABOUT 10Ah LARGER THAN BBM-A

NASDA NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN

INITIAL CHARACTERISTICS OF THE Ni-MH CELLS AT 10℃





- CHARGE & DISCHARGE CHARACTERISTICS ARE SIMILAR TO THE CHARACTERISTICS AT 20℃

NASDA NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN

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℃
	BBM-B ABOUT 10Ah LARGER THAN BBM-A	-5℃

THE CHARACTERISTICS ARE DERIVED FROM PRECHARGE

NASDA NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN

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℃	CHARGE EFFICIENCY IS LOWER THAN Ni-Cd *)
-5℃	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

NASDA NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN

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、52.5min
DISCHARGE	0.5C、30 min	0.8C、 30 min
DOD	25 %	40 %
CHARGE RETURN	105 %	
CELL TEMP.	20℃ (MAINTAIND 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=35A)

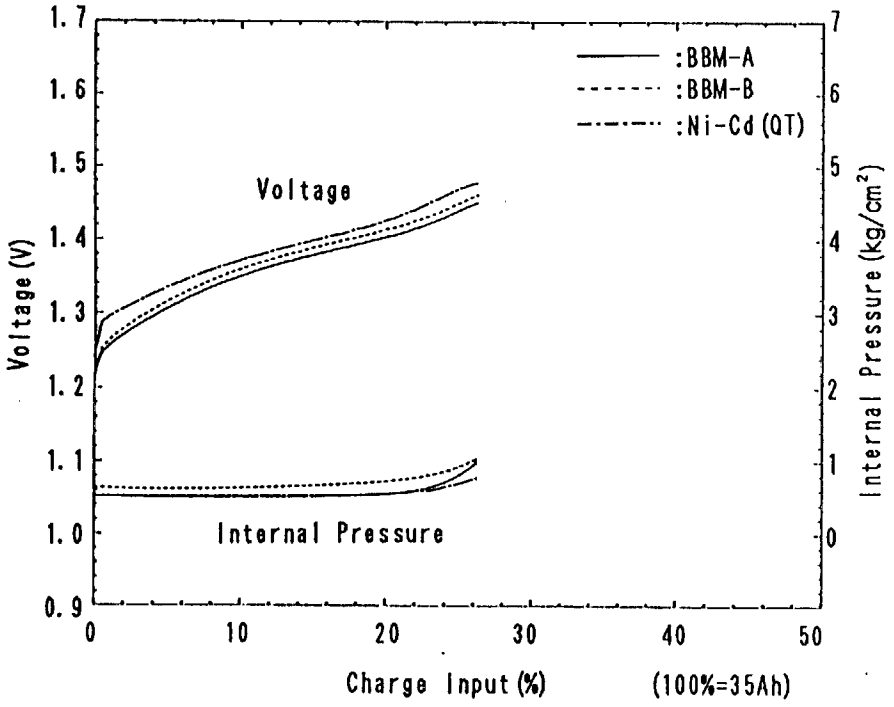
*1 : Residual Capacity is obtained by 0.5C discharge to 1 Volt after LEO cycling charge.

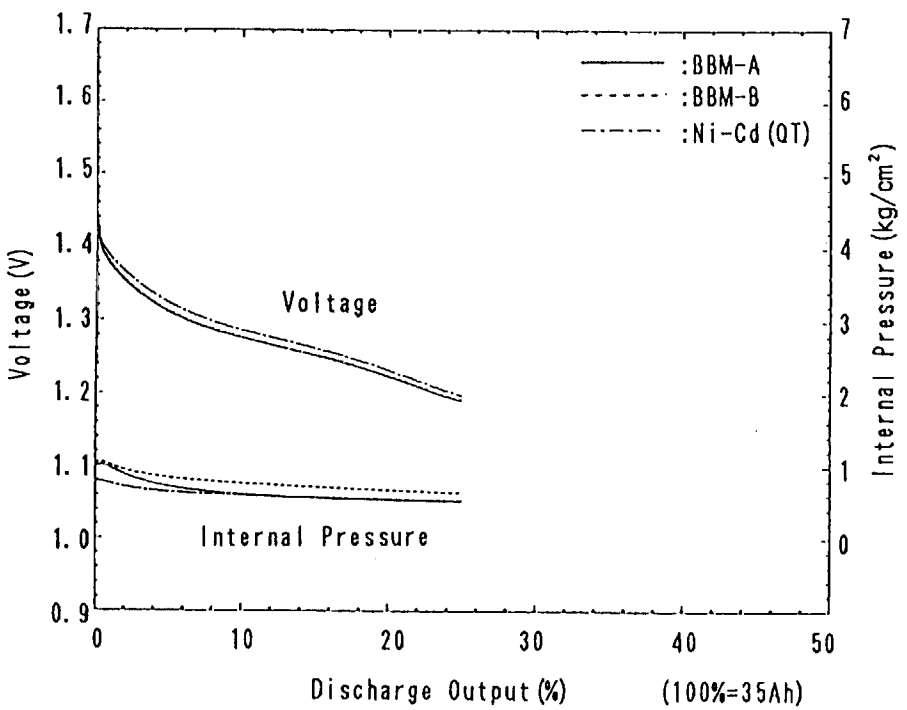
*2 : Full-charged Capacity is obtained by 0.5C discharge to 1 Volt after full-charging with 0.1C for 16hours.

NASDA NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN

25%DOD-LEO TEST OF 35Ah CLASS Ni-MH CELLS

CHARGE & DISCHARGE CHARACTERISTICS IN CYCLING AT NEARLY 3000 CYCLES



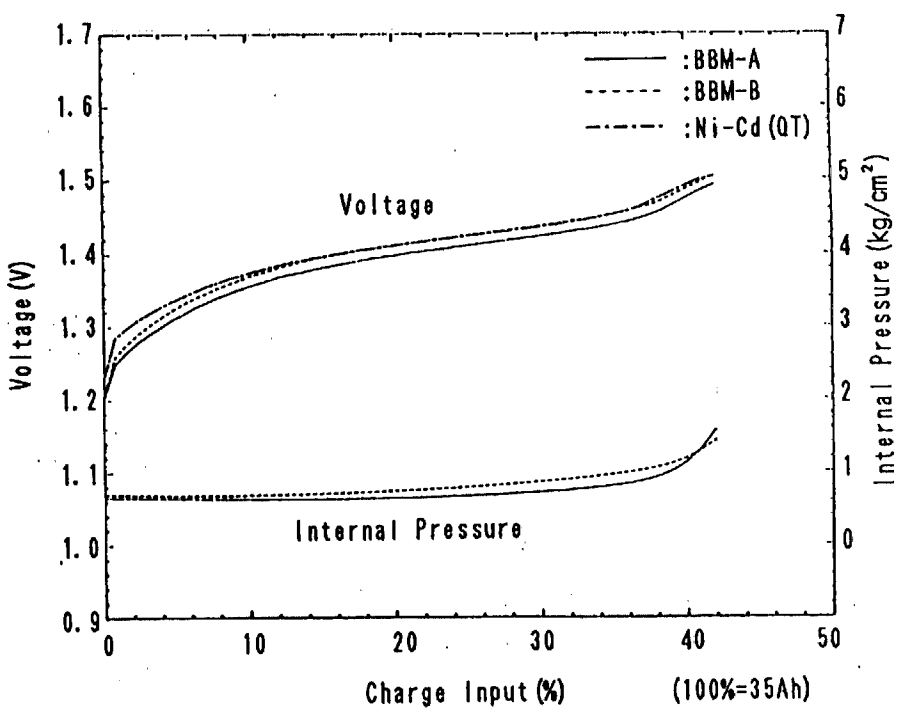


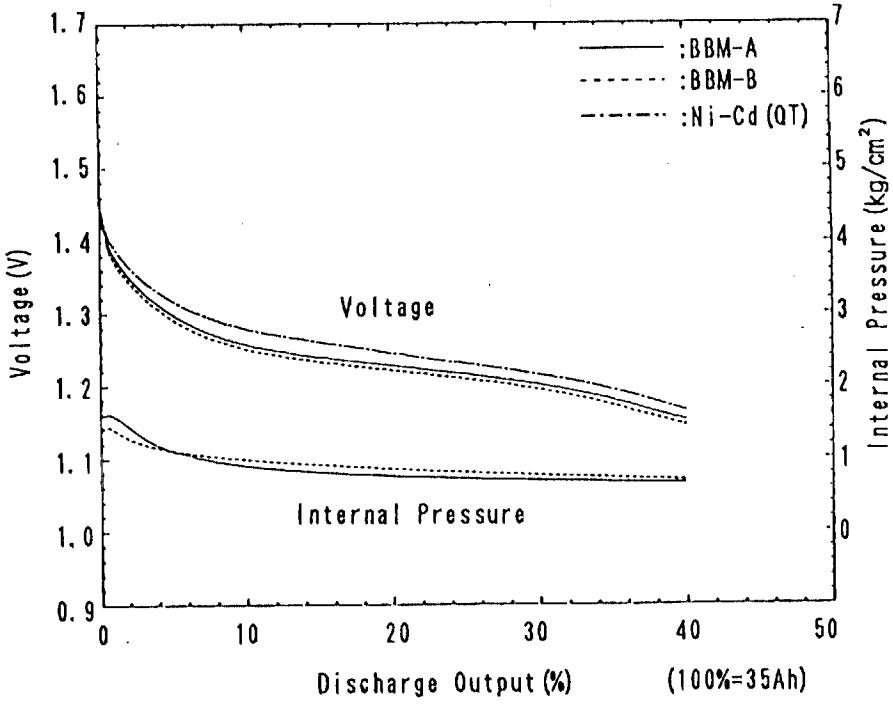
TEST CONDITION/ CHARGE : 0.3C FOR 52.5 MINUTES
DISCHARGE : 0.5C FOR 30 MINUTES (DOD : 25%)
CELL TEMP : 20℃

NASDA NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN

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

CHARGE & DISCHARGE CHARACTERISTICS IN CYCLING AT NEARLY 3000 CYCLES



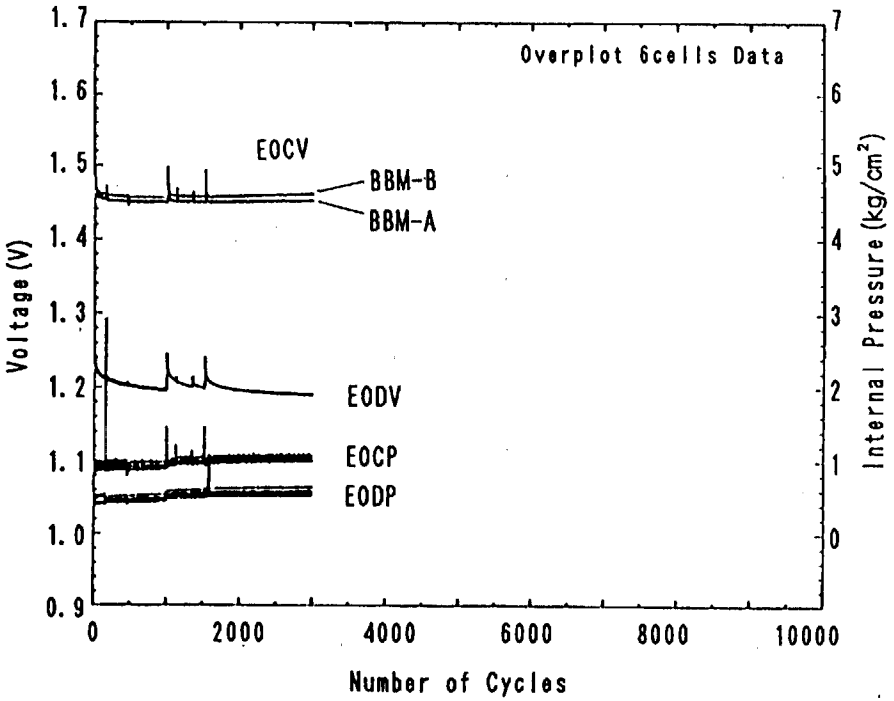


TEST CONDITION/ CHARGE : 0.48C FOR 52.5 MINUTES
DISCHARGE : 0.8C FOR 30 MINUTES (DOD : 25%)
CELL TEMP : 20℃

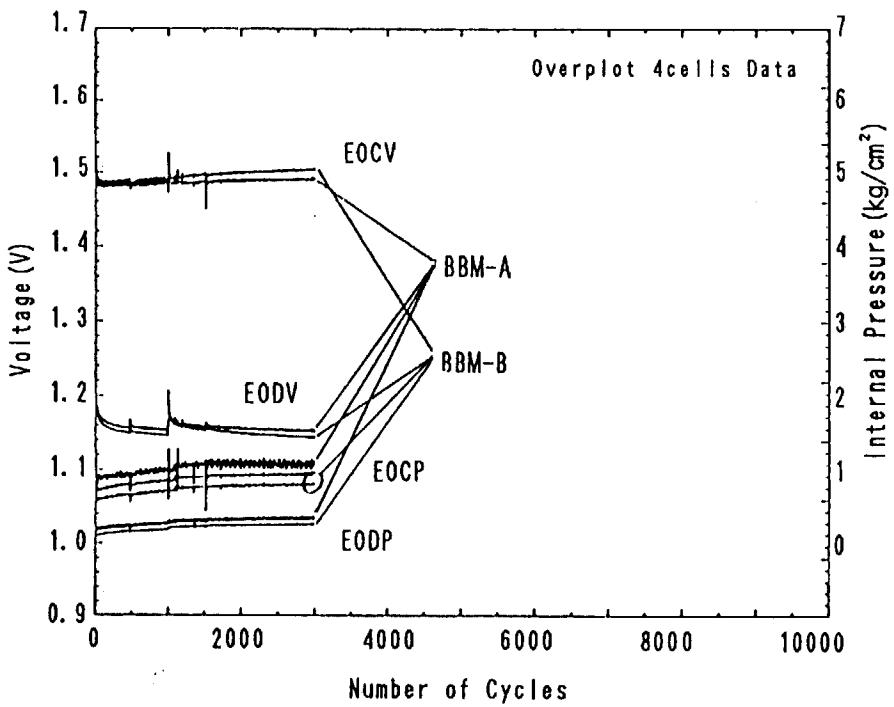
NASDA NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN

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

25%DOD



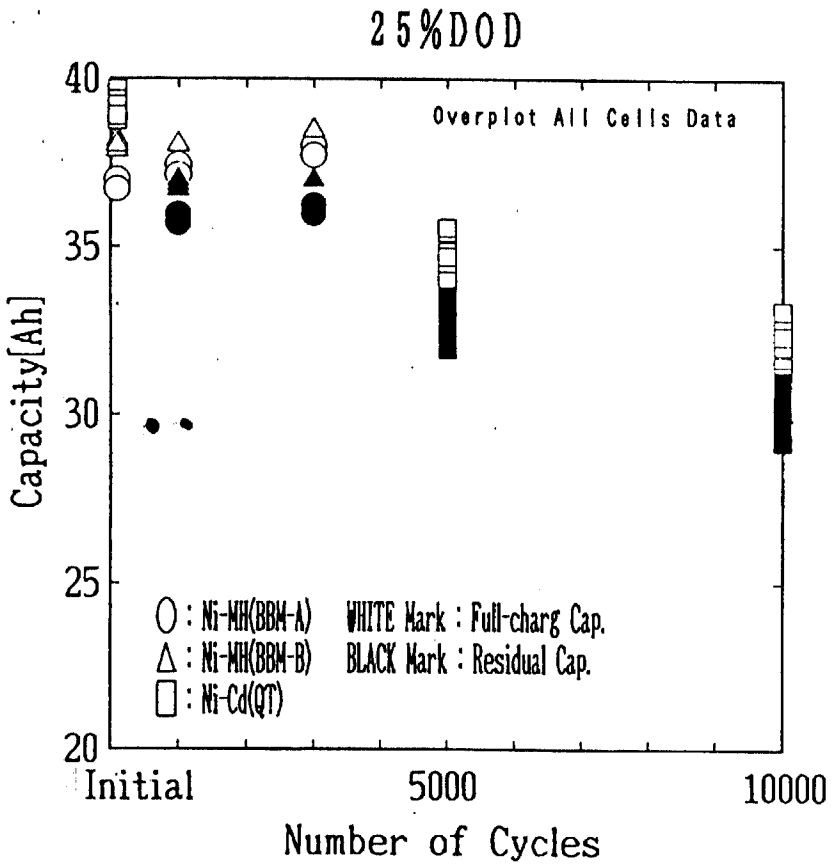
40%DOD

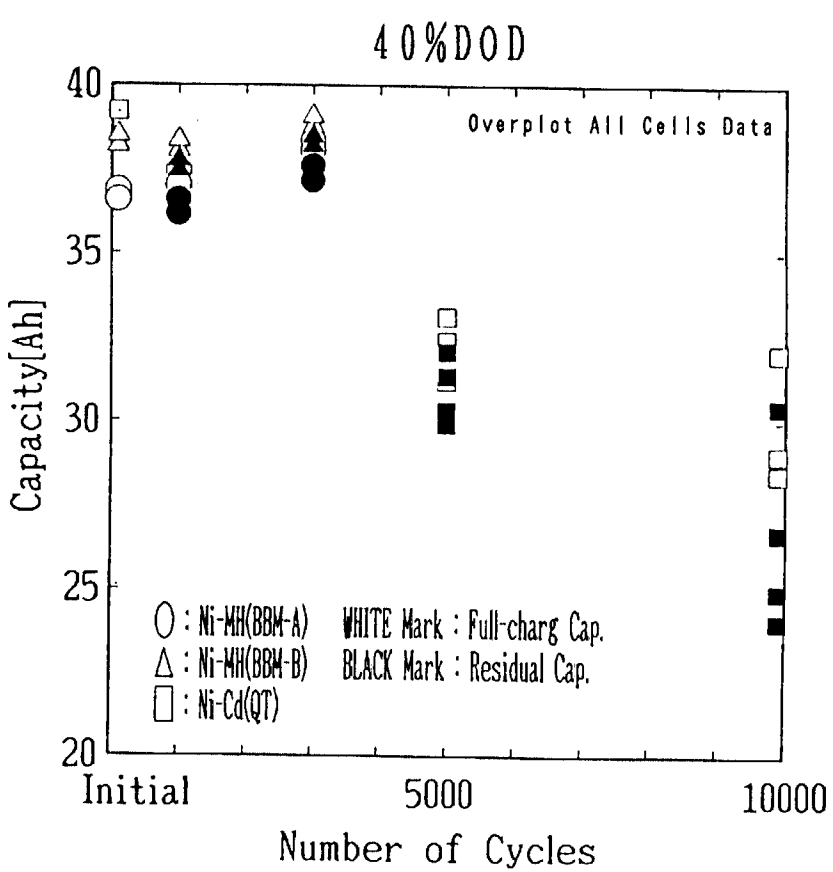


BOTH OF LEO TESTS ARE OVER 3,000 CYCLES SO FAR NO FAILURES
EOCV OF BBM-B ARE GRADUALLY INCREASING ON 40%DOD-LEO CYCLE TEST

NASDA NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN

TREND OF CAPACITIES ON LEO TEST





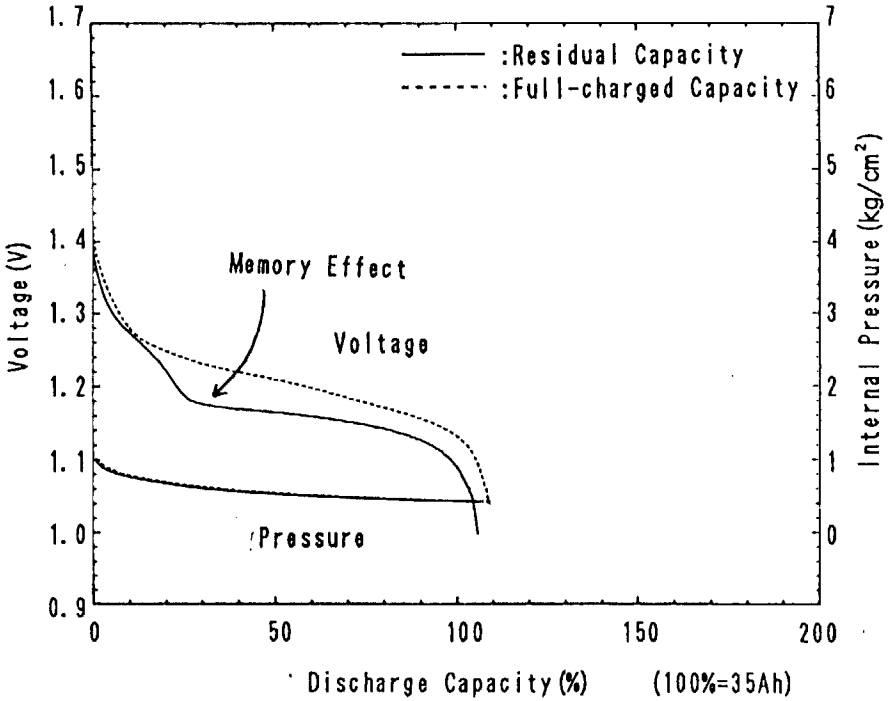
THE Ni-MH CELLS HAVE GOOD PERFORMANCE ABOUT CAPACITY REMAINING ESPECIALLY, AS SIMILAR TO COMMERCIAL Ni-MH CELLS

NASDA NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN

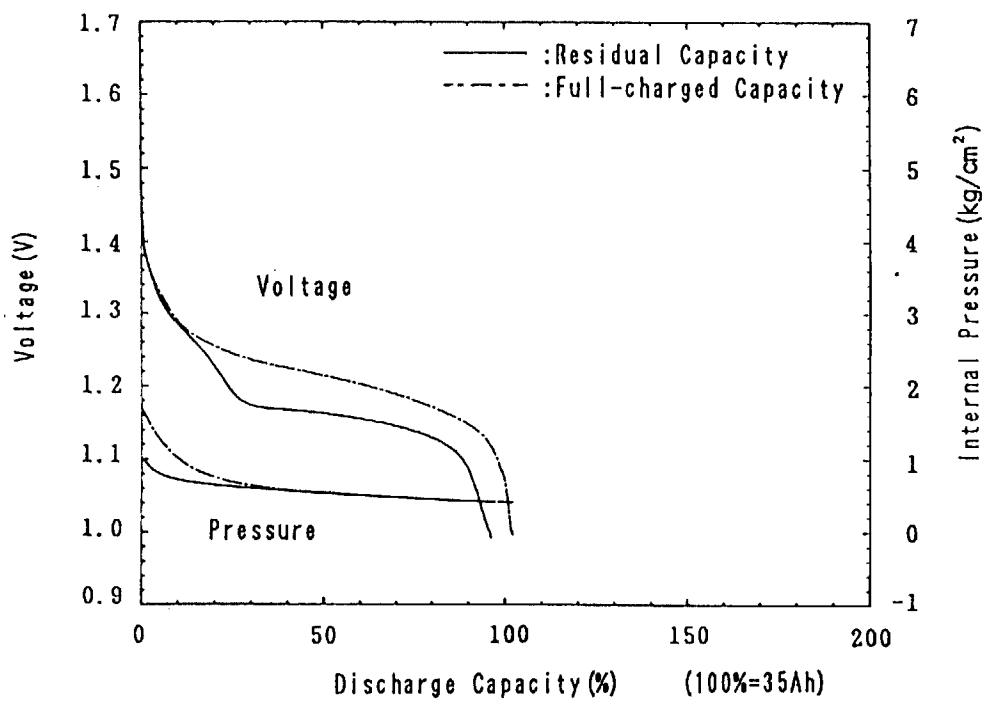
MEMORY EFFECT OF 35Ah CLASS Ni-MH CELLS

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

THE DIFFERENCE BETWEEN BBM-A AND BBM-B

CHARACTERISTICS		DOD
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%

NASDA NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN

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

NASDA NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN

CONCLUSION

EVALUATION OF COMMERICAL 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, CAUSESING LOSS OF OVERCHARGE PROTECTION

DEVELOPMENT OF Ni-MH CELL FOR SPACE USE

- WE MANUFACTURED 35Ah CLASS FLIGHT-TYPE Ni-MH CELL BASED ON THE COMMERICAL 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

NASDA NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN

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