1997 NASA AEROSPACE BATTERY WORKSHOP

CRANE CELL TESTING SUPPORT OF

Goddard Space Flight Center

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AEROSPACE BATTERY CELL TESTING

- Verification Of Secondary Cells
- Objective and Benefit

  To verify the quality and reliability of aerospace battery cells and batteries for NASA flight programs and to design the battery/cell for upcoming NASA spacecraft.

GSFC LEO PROGRAMS

PROJECT	PACK	TYPE	Ah	ORBIT CHG TYPE	DoD	°C	K CYCLE
NICKEL CADMIUM							
SWAS	6016F	SUPER	21	MISSION/A	VAR	5	12
POES	0040P	SAFT/F	40	MISSION/B	22	5	6
POES	0041P	SAFT/F	40	STRESS/B	40	20	6
POES	0042P	SAFT/F	40	STRESS/B	40	20	1
XTE	0052T	SUPER	50	MISSION/A	14.4	10	13
TRMM	0053T	SUPER	50	MISSION/A	17	0	12
TRMM	6151T	SUPER	50	MISSION/A	25	10	6
TRMM	6152T	SUPER	50	MISSION/A	17	0	7
NICKEL HYDROGEN							
LANDSAT	3050H	EPI	50	MISSION/A	20	5	10
HST	3600H	EPI	93	MISSION/C	11	-5	27
HST	3601H	EPI	93	MISSION/C	11	-5	27

Chart above shows LEO orbit packs cycling at Crane associated with GSFC flight programs. There is a total of 11 project packs currently cycling. Nine of these are mission simulation regimes and the remaining two are in a 40% DoD stress test regime.

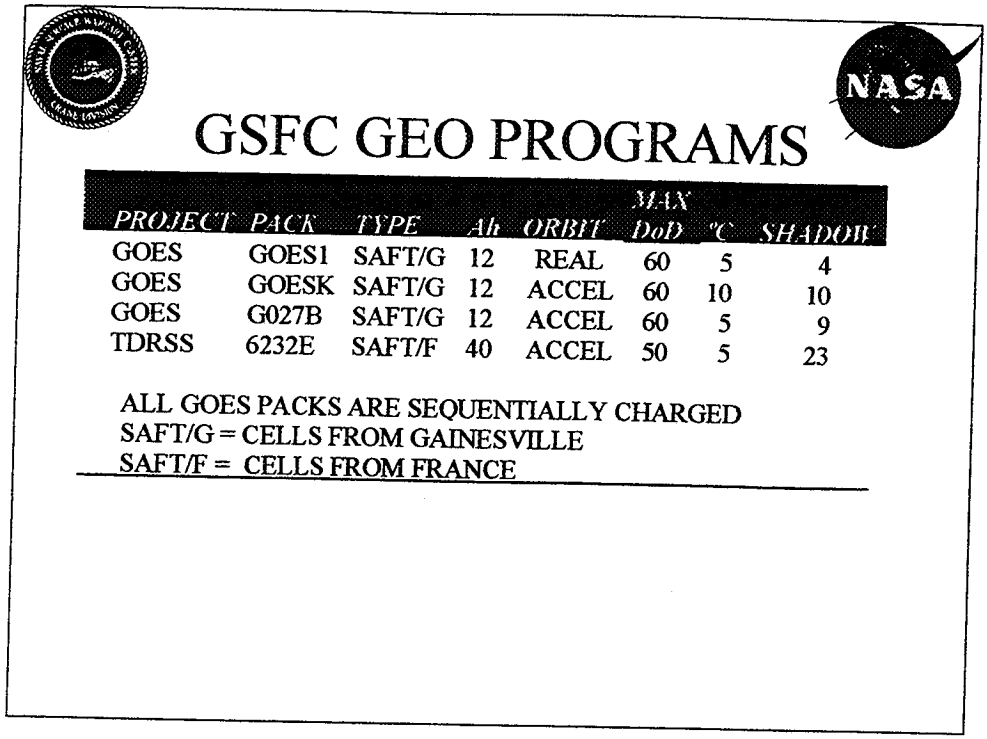
Pack 6016F is a variable DoD cycling regime. The DoD changes every 30 days with a 7 day trickle charge between changes. This sequence is 5, 20, 10, 25, 5, 10, 5, 20 and 10 percent depth of discharge and is repeated until the end of life.

Charging techniques vary for each pack and are listed below:

A. Constant current with a V/T to a C/D ratio then trickle charge.

B. Constant current with a V/T.

C. Constant current to specific voltage then trickle charge.



PROJECT	PACK	TYPE	Ah	ORBIT	MAX DoD	°C	SHADOW
GOES	GOES1	SAFT/G	12	REAL	60	5	4
GOES	GOESK	SAFT/G	12	ACCEL	60	10	10
GOES	G027B	SAFT/G	12	ACCEL	60	5	9
TDRSS	6232E	SAFT/F	40	ACCEL	50	5	23

ALL GOES PACKS ARE SEQUENTIALLY CHARGED
SAFT/G = CELLS FROM GAINESVILLE
SAFT/F = CELLS FROM FRANCE

The GOES packs, are cycled according to a 42 day GEO, with a maximum DoD of 60%. Except for GOES1 the orbits are accelerated time (six shadows per year) at 5 or 10 degree centigrade. All packs are sequential recharge at .9 amp (six minutes on, six minutes open circuit) with V/T to a specified per-cent of ampere-hour out of previous discharge. Then sequentially trickle charge at .3 amp (six minutes on, 6 minutes open circuit) with V/T for remainder of the twenty-four hour cycle.

The TDRSS pack 6232E was fabricated by TRW similar to the flight battery configuration. This included wrapping each cell in a layer of fiberglass, inserting thermal shims between cells and bonding the cells to the shims with RTV, and compressing the pack to a mechanical pre-load similar to the flight pack (63 psi). The cells are cycled according to a 45 day accelerated GEO cycling regime (12 hour orbit) with a maximum DoD 50%. Pack temperature is controlled by a cold plate.

DISCONTUNUED LEO PACKS

PROJECT	PACK	TYPE	Ah	ORBIT	DoD	°C	K CYCLE
TOMS	6090T	SUPER	9	STRESS	50	20	20
SAMPEX	0090B	SUPER	9	MISSION	12	5	18
SWAS	6015F	SUPER	21	STRESS	50	20	13
HQ	6140S	SAFT/F	40	STRESS	40	20	20
NOAA	NOAA1	SAFT/G	47		VAR	5	5

PACK	COMMENTS
6090T	LOW EODV ,CHARGE CROSSOVER DIVERGENCE 138 MV
0090B	CHARGE CROSSOVER DIVERGENCE 148 MV
6015F	EOC DIVERGENCE 132 MV
6140S	EOC DIVERGENCE 65 MV, LOW EODV, HI C/D, C-4 INTERNALLY SHORTED
NOAA1	C-2 INTERNALLY SHORTED

SAFT/G = CELLS FROM GAINESVILLE
SAFT/F = CELLS FROM FRANCE

Pack 6090T at start of cycling repaired leaky pressure fitting connector on cell 5. Cell 5 removed on cycle 4150 because of high charge voltage and sent to Comsat Labs for DPA.

Pack 0090B on cycle 4110 repaired leaky pressure fitting connector on cell 5. Cell 5 removed on cycle 7171 because of high charge voltage and sent to Comsat Labs for DPA. After completing 8000 cycles cell 1 pressure gradually increased over a period of 400 cycles. Several reconditioning cycles were performed in attempt to control pressure. Recharge trip was then changed from 104 to 100 percent on cycle 11,454 and pressure returned to nominal.

Pack 6015F. Charge divergence began after 10000 cycles and gradually increased though-out life.

Pack 6140S These cells were designated as the standard design aerospace nickel-cadmium cell and were from of lot 196 .

NOAA1 Cells 1 through 8 are lot 6 cells and were from packs 0648N and 0649N. Cells failed because of charge divergence after completing over 2900 cycles. Cells 9 through 17 were 42 Ah Mars Observer cells. The purpose of the test was to investigate the effects of divergence in a battery pack containing more than 10 cells.

DISCONTINUED GEO PACKS

PROJECT	PACK	TYPE	Ah	ORBIT	DoD	°C	SHADOW
GOES	6227B	SAFT/G	12	REAL sequential	60	5	25
GOES	6227C	SAFT/G	12	ACCEL sequential	60	0	34

PACK	COMMENTS
6227B	COMPLETED MISSION
6227C	COMPLETED MISSION

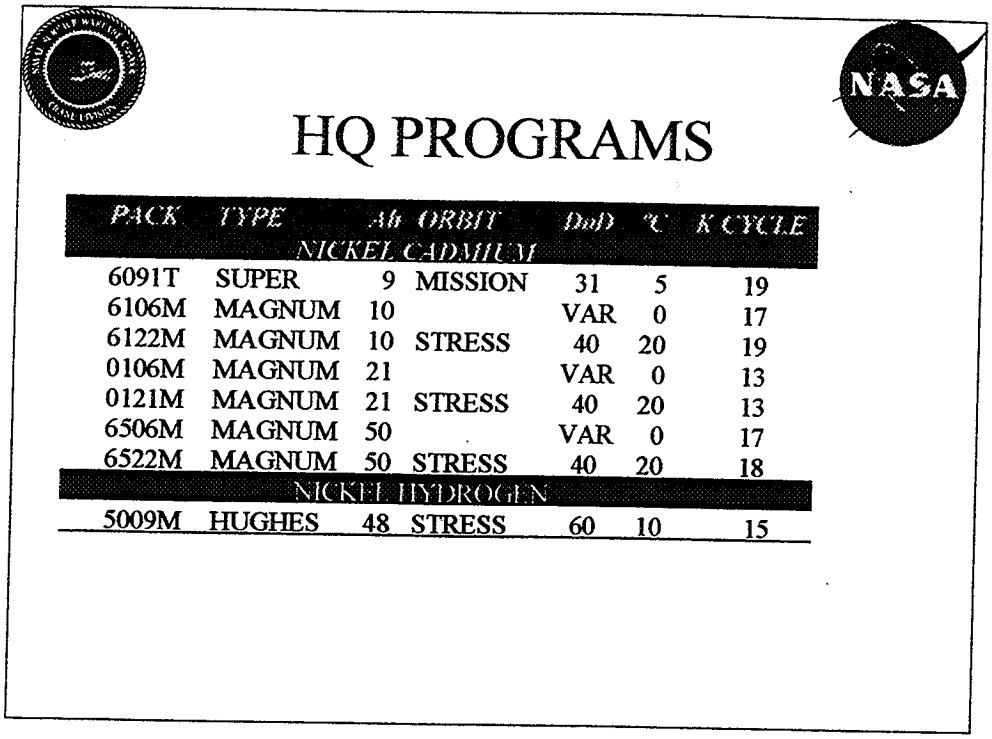
SAFT/G = CELLS FROM GAINESVILLE
SAFT/F = CELLS FROM FRANCE

Pack 6227B was a real time test but after completing the mission requirements of 13 shadow periods it was changed to accelerated orbit similar to pack 6227C.

Packs were cycled according to a 42 day GEO regime with a maximum of 60% DoD. The orbit was accelerated time at 0 or 5 degree centigrade.

They were sequential recharge at .9 amp (six minutes charge, six minutes open circuit) with V/T of 1.482 v/c to 115% or 1.508 v/c to 120% of ampere-hour out of previous discharge. Then sequentially trickle charge at .3 amp (six minutes charge, 6 minutes open circuit) with V/T for remainder of the twenty-four hour cycle.

Packs were discontinued after completing mission requirements and special mission unique test.



Packs with DoD identified as variable (VAR) are being cycled as follows: The first 2000 cycles DoD was 10 per-cent. The next 2000 cycles DoD was increased to 25 per-cent. Then DoD increased to 50 per-cent for 2000 cycles. This sequence is repeated until the end of life.

MAGNUM PACKS

PACK TEMP	Ah	% DoD	CHG RATE	V/T	% C/D	DIVERGENCE CROSS	DIVERGENCE EOC	AVG EODV
6106M 0°C	10	10	C	1.440	108-109	28	3	1.214
		25	C	1.460	104-106	32	8	1.181
		50	C	1.480	102-103	26	6	1.134
6506M 0°C	50	10	C	1.420	101-102	3	1	1.206
		25	C	1.440	102-103	4	1	1.166
		50	C	1.460	102-103	7	2	1.137
0106M 0°C	21	10	.5C	1.420	112-113	8	2	1.226
		25	.5C	1.460	112-113	6	2	1.177
		50	C	1.480	107-108	6	2	1.090
6122M 20°C	10	40	.8C	1.454	108-112	4	4	1.127
6522M 20°C	50	40	.8C	1.454	108-112	4	4	1.128
0121M 20°C	21	40	.8C	1.445	110-120	7	2	1.127

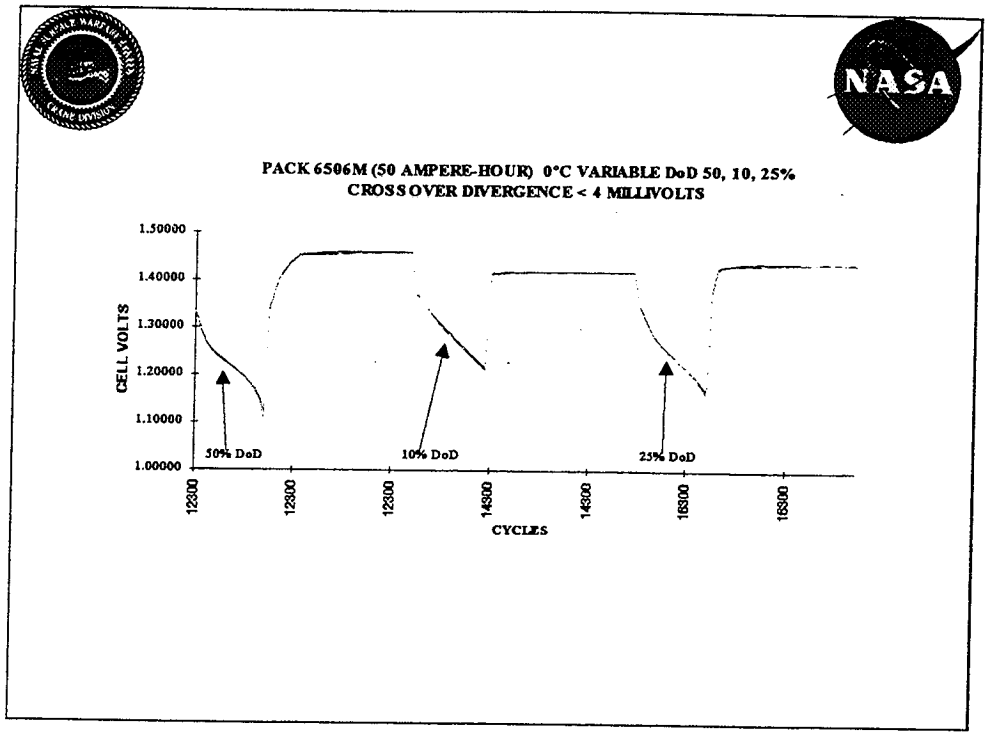
Due to the anomalous capacity and voltage performance of Super and Magnum cells have experienced at low temperatures (-10 to 5° C). A program was initiated to test a sampling of these cells at either a particular mission profile or at low temperature with variable DoD's.

The C/D ratio given in chart is the normal operating range for the cycle life of pack.

The 10 and 50 Ah cells are cycled with the same parameters the only difference being the voltage limits for 10 Ah pack 6106M is 20 millivolts higher at all levels.

Recharges were higher for the second sequence of 10% DoD

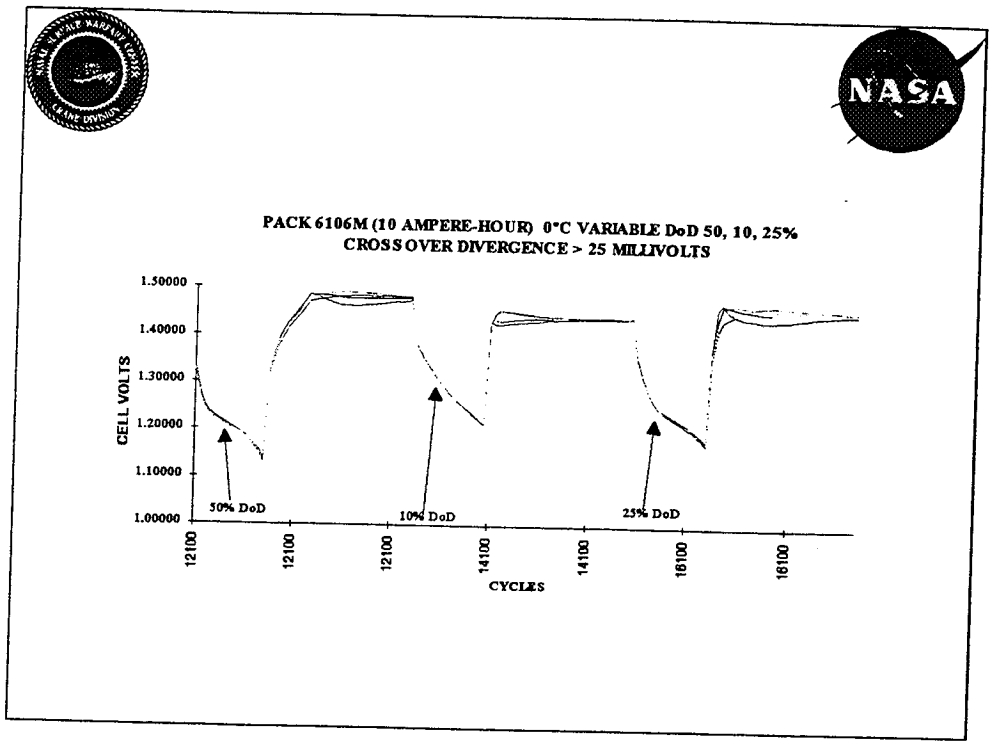
Packs 0106M and 0121M (21 Ah cells) recharges are higher than other packs for the same voltage limit. This is true for both test regimes.



Plots shows each of the six cells of the pack during a full charge and discharge cycle at 50, 10 and 25 depth of discharge . There is very little charge divergence(4 millivolts) in pack.

Crossover occurs when the charging regime is changing from constant current to a constant potential.

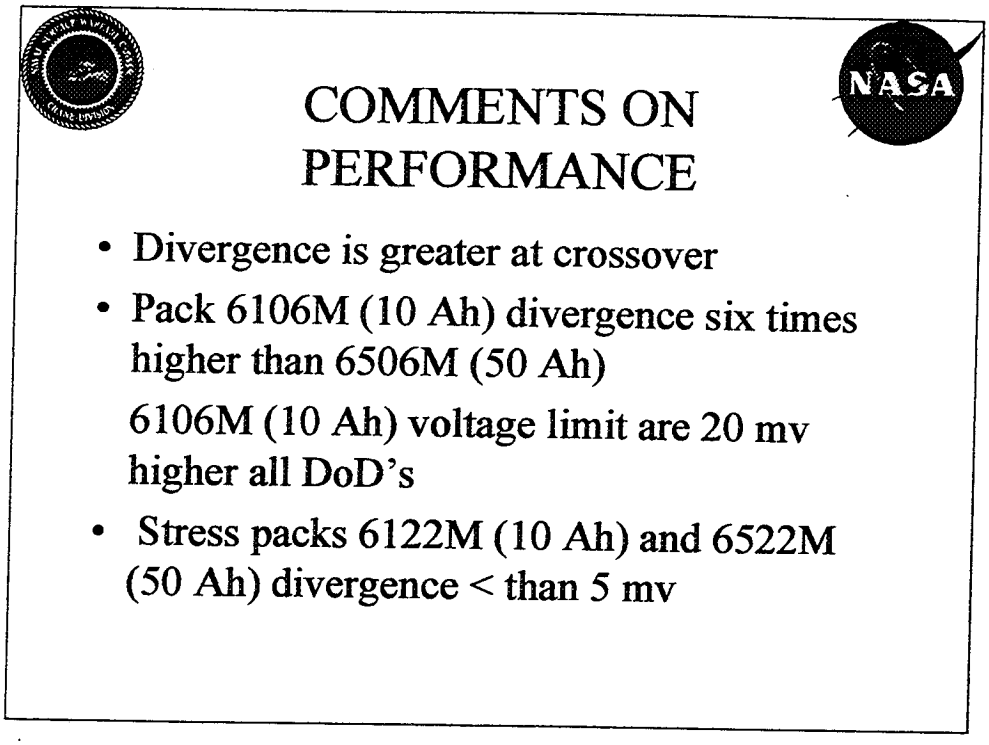
The voltage limit on the 50 Ah pack 6506M was decreased by 20 millivolt (1.420 volts) after 900 cycles into the second sequence of the 10% DoD test. This was done because of recharges above 119%. This resulted in no increase in the end of charge divergence or significantly decreasing the end of discharge voltages.



Plots shows each of the six cells of the pack during a full charge and discharge cycle at 50, 10 and 25 depth of discharge. Charge divergence varies from 26 to 32 millivolts.

Crossover occurs when the charging regime is changing from constant current to a constant potential.

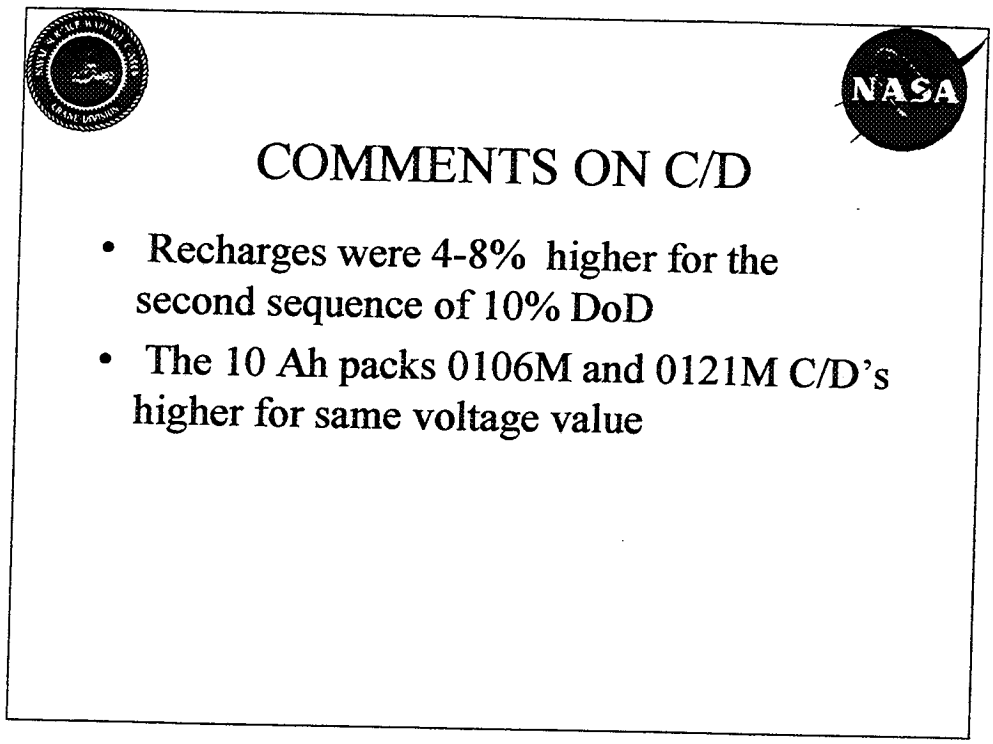
The voltage limit for the 10 Ah pack 6106M was increased by 20 millivolts (1.500 volts) for approximately 1700 cycles . This occurred around 4600 cycles and during the 50% DoD test. This increase in voltage did not improve charge voltage divergence or significantly improve end of discharge volts. The 50%DoD was returned to the 1.480 volt level after this sequence.



Crossover occurs when the charging regime is changing from constant current to a constant potential.

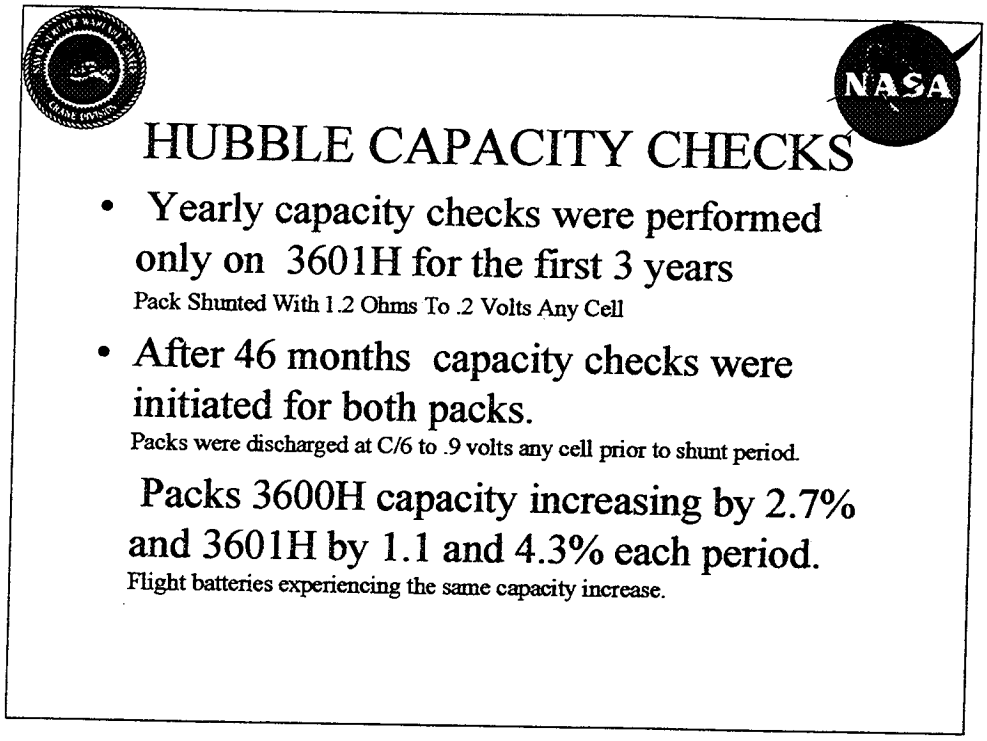
The 10 Ah pack 6106M divergences is six times greater than the 50 Ah pack 6506M. All testing parameters are the same except 6106M voltage level is set 20 millivolts higher than 6506M.

Their sister packs in the 20 °C 40% stress regime testing parameters are identical. However their C/D's and end of discharge voltages are very similar.



Recharges were 4 to 8 percent higher on the second sequence of 10 % DoD.

The 10 ampere-hour packs C/D's were 5-10 percent higher for the same voltage level when compared to the 21 and 50 ampere-hour packs.



The ten cells used in these two packs were manufactured by Eagle-Picher Industries, Inc. (EP) for the Hubble Space Telescope (HST) project and are from the Flight Module 1 and Flight Module 2 lots. The cells from pack 3600H are from lot FM1. The cells from pack 3601H are from lot FM2 which is the same lot as the cells that have been in orbit on the HST spacecraft since April 24, 1990.

Both packs followed the same set of parameters except pack 3601H which was reconditioned after each yearly shadow period. A resistor of 1.2 ohm was placed across pack until any cell reached .2 volts.

This procedure was changed after 46 months. Both packs are now reconditioned has described below:

Charge 9.3 amp for 10 hours

Charge 4 amp for 14 hours

Discharge 15 amp to .9 volts first cell

Shunt pack with 1.2 ohms to .2 volts first cell

Sequence performed a total of five cycles.

The capacity growth during capacity checks is similar to increase's experience by the flight battery.