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BRASILSAT A2 - GROUND AND IN-ORBIT ANOMALIES

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ABSTRACT

A description of the anomalies encountered during ground preparation for launch and in-orbit operation of Brasilsat A2 batteries is given.

Processes used during recovery of these batteries and the improvement on main parameters are discussed, covering many cycles of reconditionnings and behaviour during SEPTEMBER/86 eclipse charge/ discarge cycles.

INTRODUCTION

Brasilsat A2 is a HS-376 Spacecraft that uses 2 NiCd batteries. They were formed from cells that came from two different lots under GE fabrication/inspection procedures.

These cells were activated in October 1984 because initial planning had A2 launch sheduled for August 1985. This date was delayed to March 1986 when was finally launched from KOUROU (French Guiana).

During the tests at the manufacturer, no anomalies were reported with the lots and, the capacities and mass values measured, were all compatible with the size of the cells. Also agreeded with the numbers seen in A1 cells.

Based on the HUGHES criteria (higher capacities/lower masses) the cells were selected and some adittional testing were carried out which showed no strange behaviour.

In January 1985, the cells were assembled in packs at KANATA (SPAR facility) and the first reconditionning at this level was made (march 1985), showing good results in terms of capacity and cell voltages. After that, followed a 2 month period at ambient temperature mounted on the S/C for the mass-properties.

Right after that, the batteries had their F.A.T. (june/85) which presented good results, comparable with the ones previously seen.

From June until October/85, the packs went to cold storage and then, had two reconditionning cycles at 20° C and 10° C as preparation for the launch campaign. During these cycles, no abnormal values were registered, assuring that no degradations were caused due to the storage, except for the failure in the final "retention test" of one cell in battery 1. A similar test was performed (10 min of boost charge + 24 hours stand) and all cells passed. The failure was considered not too serious, because the cell voltage was below but close to the minimum required value (MIN = 1.15V and cell voltage at 1.065 Volts).

CAMPAIGN (FIRST PHASE)

The packs were then shipped to the launch site (KOUROU) and as they arrived (MID-OCTOBER), an initial 40 hours charge at C/20 (1.2 Amps) was initiated. For this charge a few air conditioners/ fans were used in order to maintain pack temperatures at low values (24° C) even after reaching ROLLOVER. During the charge, it was noticed that 3 cells didn't have a ROLLOVER. But this phenomena was explained by the fact that the cells were all placed at extremes of the packs thus, having a more efficient cooling effect, that forced the cells temperature down. Consequently, the cell voltages remained at their PEAK values.

After this initial charge, the batteries were kept on a weekly TOP-UP regime (charge at C/10 until PEAK + 30 min). In the beginning of the first TOP-UP (31/OCT/85) it was observed that cell # 17 on battery 1 had a voltage about 12 mV (2 bits on TM) below the whole group. This difference persisted throughout the charge. The subsequent TOP-UP's (NOV 8th and 14th) showed the same behaviour, making believe that this particular cell had a higher self-discharge current when left on open circuit.

With the postponement of the launch date to FEB/86, it had been decided a break on the campaign, leaving the batteries discharge/shorted and mounted on the S/C, due to the period of storage (10 weeks) and to minimize the handling.

Thus, a discharge happened on NOV 14th and a small decrease in measured capacities was observed (Table 1). Cell # 17 on battery 1 was the lowest cell, confirming the suppositions.

PHASE	BATTERY 1	BATTERY 2
KANATA	26.13	26.65
14.11.85	25.95	26.13
24.01.86	24.45	25.01
28.01.86	24.83	25.20
29.01.86	24.45	25.01

TABLE 1 - Capacity Variation

NOTE: Values in Amp. hours

The storage period finished on JAN 22nd, when batteries were charged for 40 hours at C/20. The maximum voltage values recorded during this charge, revealed an increase of about 18 mV (3 bits) as shown in Table 2.

PHASE	BATTERY 1	BATTERY 2	TEMPERATURE
OCT 25th	1.459 V	1.453 V	$\simeq$ 23 C
JAN 22nd	1.477 V	1.474 V	$\simeq$ 22 C

TABLE 2 - Maximum cell voltages(at 1.2 Amps)

As per Hughes recommendation, 3 extra cycles were performed on these batteries. A summary of these cycles is given in Table 1, which shows a reduction in capacity values of $\simeq$ 6% compared to the NOV 14th discharge. The charges at C/10 had to be interrupted because of high cell voltage problems (exceeding the VxT curve), causing shifts on the limiting curve and reduction on the rates in order to complete the charges. Table 3 shows a comparison of the maximum cell voltages in two charges at C/10, before and after the storage.

PHASE	BATTERY 1	BATTERY 2	TEMPERATURE
F.A.T.	1.489 V	1.481 V	$\simeq$ 20 C
JAN 27th	* 1.508 V	* 1.506 V	$\simeq$ 21 C

TABLE 3 - Maximum cell votages (at 2.4 Amps)

* Charge aborted

From the end of January until the launch day (March 28th) the batteries experienced 3 different management procedures. Initially, we started with the tradicional TOP-UP (C/10; once a week) that was accumulating to much time in open-cricuit stand, agravating the spread on cell voltages (specially on battery 1) and, not bringing any significant improvement on the high voltage problem.

On March 11th the rate was changed to a Tricke charge ($\simeq$ C/50), which was applied daily for about 10 to 15 hours (limited by maximum temperature allowed = 29.4 °C). The result was a better equalization of the cells at end-of-charge, although the other mentioned anomalies remained unchanged.

IN-ORBIT BEHAVIOUR

After launch, in the initial transfer orbits, the stop charge criteria used didn't allow batteries to reach the ROLLOVER thus, hiding the high voltage problem. A few hours after the panel was deployied, the Trickle charge was turned ON. The pack temperatures were around 10° C and in less than 2 hours many cells had exceeded the limit (Table 4), causing the interruption of the charge.

PACK (°C) TEMP.	5	6	7	8	9	10	11	12	13	14	15
MAXIMUM VOLTAGE(V) TRICKLE	1.484	1.482	1.480	1.478	1.476	1.474	1.472	1.470	1.469	1.467	1.465
MAX. VOLT. AT C/10	1.539	1.537	1.534	1.531	1.529	1.526	1.524	1.521	1.519	1.516	1.514

TABLE 4 - Charge Limit

For the last 15 days of eclipse in this season, the recharge management was:

a) Charge at (M+T) or C/20 until limit is reached (Table 4);

b) Try once a day a Trickle charge;

c) Leave in open-circuit for the rest of the day.

This procedure was enough to support these discharges.

RECONDITIONING CYCLES

The proposed "solution" for the problems was to have the batteries reconditioned a few times (Table 5), until it accepted the trickle charge whithout exceeding any limit

BAT	1st CYCLE	2nd CYCLE	3rd CYCLE	4th CYCLE
1	April 21st	May 21st	May 26th	June 1st
2	May 5th	May 12th	-	-

TABLE 5 - RECONDITIONNING SCHEDULE

Battery 1

In the first cycle (April 21st), the results obtainned showed a highly reduced capacity (Table 6), probably due to cell # 17. During the charge, at about 105% of the removed capacity, cell 32 exceeded the C/20 limit. This battery maintained its behaviour on Trickle, although showed some improvement.

TABLE 6 - Capacity Evolution

CYCLE	** EXPECTED VALUES	1	2	3	4
BAT 1	≅ 29.00	24.18	23.77	26.93	26.76
BAT 2	≅ 29.58	* 26.94	27.70	-	-

* Values in AH
** 111% of the FAT values

The second cycle accurred only on May 21st, after the two reconditionnings on battery # 2, before which it had been maintainned by a 2 trickle charge tries per day routine. This one month period, removed the small improvements caused by the first cycle.

The results showed a further reduction in capacity and the charge (C/20) stopped at 103% return, with higher average cell voltage.

Other two cycles were performed, and the capacity suffered a big increase (≅ 3 AH). The cell voltages had a smaller spread at ROLLOVER, with a reduction on the rise rate (mV/min). The Trickle charge was applied without problems, although the C/20 rate still had to be interrupted (at ≅ 104% return).

Battery 2

It was first cycled on May 5th, also presenting a large reduction in capacity (Table 6) and having to stop the charge prematurely (≅ 107%), because of cell # 20 excessive voltage. Trickle charge was still forcing the cells to go above limits. The second cycle (May 12th), showed a 0.76 AH increase in capacity. Although still having the (M+T) charge aborted at 106% return, the trickle charge was fairly well accepted be the cells.

A smaller charge rate (≅ 0.2 Amps) was used between the reconditionning cycles, and proved to have helped a lot on equalizing the cells before the subsequent discharge, decreasing significantly the spread, without making the cell voltages go above to limits.

AUGUST RECONDITIONNING PERFORMANCE

During the August/86 reconditionning, a relevant enhancement was verified in all parameters. The capacities increased almost to the expected values (Table 7) and the cells could be charged at the C/20 rate without exceeding significantly the limits (maximum 3 mV = 1/2 bit). These improvements were probably caused by the long period in the trickle charge rate, that helped equalizing the state of charge of the cells and breaking the "big cristals" formed in the overcharge protection region of the plates, called as responsible for the high voltage anomaly.

BAT	CAPACITY (AH)	MAX. CELL VOLT.	TEMPERATURE	LIMIT
1	27.91	1.534 V	8 ° C	1.531 V
2	28.85	1.512 V	8 ° C	1.531 V

TABLE 7 - August/86 Reconditionning

The September/86 eclipse season, demonstrated how healthier these batteries are now, showing values very comparable with the ones achieved by the Satellite A1 batteries. Although the average cell peak voltage is still above the normal (A1) values by about 30 to 40 mV, we've got confidence that with the next 4 month period of continuoos trickle charge, the performance in the following season (March/87) will show even better results.

CONCLUSION

It has been presented the sequence of events occurred with the Brasilsat A2 batteries . The long short-circuited in ambient stand period seems to have been the main reason for the major anomalies encountered in the operation of these units. Although it didn't take too long for the problems to arise, the process of removing this uncomfortable behaviour, has been predicted as an arduous and long period. Up to now, a number of reconditionnig cycles have been applied with significant improvements in performance. At least, now we can be sure that no permanent degradation occurred, and the life of these batteries shall not be affected.