LONG LIFE COMMUNICATION SATELLITES: ELECTRIC POWER SUPPLY DURING THE ECLIPSE PERIOD

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Translation of "Satellites de communication a grande duree de vie: Fourniture de l'energie electrique durant la periode d'eclipse". IN: European Capabilities for Space Applications (Conference held 27-29 May 1975 Noordwijk, Neth.), European Space Agency, Paris (France) 1975, 9 pp.

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16. Abstract

The electric batteries, essentially nickel-cadmium, for French satellites such as D1 A, D1 C, D1 D, D2 B, D5 A, D5 B, etc., and the batteries for such satellites as SYMPHONIE, ANS, INTASAT, ESRO 4, and COS-B are discussed. The experience obtained led to the development of long lifetime batteries for communication satellites. Real simulation tests showed a lifetime of four years and accelerated lifetime tests of twelve years. These batteries will be applied in OTS, METEOSAT, and MAROTS. At the same time, new batteries are being developed, based on nickel-hydrogen or on silver-hydrogen, which should provide longer lifetimes and better reliability.

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LONG LIFE COMMUNICATION SATELLITES:
ELECTRIC POWER SUPPLY DURING THE ECLIPSE PERIOD

S. Font* /1**

SUMMARY

After having provided the batteries (Ni-Cd essentially) for most of the French satellites: D1 A, D1 C, D1 D, D2 B, D5 A, D5 B etc... SAFT also provided these for the national and European satellites such as the SYMPHONIE, ANS, INTASAT, ESRO IV, COS B.

Experience obtained during these programs allowed us to enter a new stage, which led to the definition of accumulators which can respond to the severe lifetime requirements of communication satellites. Endurance tests were performed at SAFT. Up to the present they have shown a lifetime greater than four years for real simulations and a lifetime of 12 years for accelerated tests. The recent ESRO programs: OTS, METEOSAT, MAROTS are the beneficiaries of such tests.

At the same time, SAFT is pursuing research and development work in order to increase the lifetime and reliability of Ni-Cd batteries, and to develop a new improved mass energy system such as $Ni\text{-}H_2$ and $Ag\text{-}H_g$.

* Aerospace Section - SAFT - ROMAINVILLE
** Numbers in margin indicate pagination of foreign text.

I. INTRODUCTION

A satellite has to remain active, that is, it has to be capable of selecting information and transmitting it to ground stations. For this it is necessary that the instrument be supplied with electrical power. Theoretically, numerous solutions are possible: use of solar energy, nuclear energy, electrochemical energy and mechanical energy. In practice, in most cases, the satellites have solar cells, which are combined with electrochemical generators or accumulator batteries.

The accumulator battery is charged during the "day" periods by solar cells. At night they provide the electrical power for the satellite. In general, during periods of solar irradiation, they also provide peak loads of power, when the power required is greater than can be delivered by the solar generator output.

In order to meet the requirements of the satellite, the batteries have to have the following characteristics:

- have a large lifetime. In other words, they have to provide the required energy for the required number of charging and discharging cycles (eclipse)

- they have to withstand overcharging without damage, that is an amount of electricity which is greater than that required for recharging.

- provide a sealed operation and they must resist the high mechanical stresses during launch .

Since 1963, SAFT with the support of the CNES has created a space section. The means required for studying and fabricating electrochemical generators for space applications are provided in this section.

II. SAFT EXPERIENCE IN THE AREA OF SATELLITES

Essentially there are three types of electrochemical generators which satisfy all or part of the requirements mentioned above.

These are the Ni-Cd, Ag-Cd and Ag-Zn systems with alkaline electrolytes.

The two latter systems are associated with important problems in applications, which are difficult to resolve.

Ag-Cd is interesting from the energy per mass point of view* (45 to 50 Wh/kg). These have a limited lifetime because /3 of the rapid migration of the silver. In addition, it can only be used for a relatively small discharge depth, which then reduces its appeal from a weight point of view. In fact, this system is only used when there are severe magnetic constraints.

Ag-Zn is the most favorable in terms of mass energy* (80 to 100 Wh/kg). This has an extremely short lifetime because of the formation of dendrites at the zinc electrode. The Ni-Cd system with a reduced energy mass performance * (30 Wh/kg) has an exceptionally high lifetime compared with the previous systems. It also has great flexibility in applications. Therefore, it is widely preferred as an electrochemical generator in space.

The other possible systems, especially fuel cells, are used under very specific conditions. They do not seem to be a possible candidate for communication satellites.

The first accumulator for space applications which developed from the SAFT studies, was a Ni-Cd having a cylindrical geometry and rolled up electrodes, with a nominal capacity of 3.5 Ah.

The studies were primarily concerned with hermeticity, resistance to mechanical stress and cycling performance.

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* With respect to the real capacity of the battery.

This type of cylindrical accumulator was used with success in many French satellites: D1 A, D1 C, D1 D, D5 A, D5 A and also national or European satellites: SYMPHONIE, ANS, INTASAT, ESRO IV, COS B.

Most of the satellites except for COS B and SYMPHONIE were placed in a low orbit. The duration of the mission was less than two years.

The rapid development of communication satellites placed in a high orbit (geostationary) and the associated payoff criterion led to a substantial increase in the lifetime and general performance requirements.

In order to respond to this requirement, SAFT developed a new generation of Ni-Cd accumulators with parallelepiped configuration. The range now in existence extends from a nominal capacity between four and 26 Ah. /4

These accumulators utilize the technical progress obtained over the last few years

Program	Type	Real capacity Ah	Mass	Mass Energy Wh/kg
D5 B	13 VR 3,5DS	4,2	3,100	22,02
INTELSAT V	33 VO 26S	32	48,000	27,50
INTASAT	12 VR 3,5DS	4,2	2,820	22,34
COS B	18 VO 6 FS	7,2	5,900	27,46
METEOSAT	16 VO 7S	8,4	6,430	26,13
OTS 2914	28 VO 7S	8,4	11,360	25.8
OTS 3914**	14 VO 18S	20	12,300	[illegible],45

* Calculated from the real available capacity and a nominal voltage of 1.25 V.
** Estimate

- ratio of negative to positive capacity graded in 1.5
- adjustment to the charging state of the negative electrode (precharge)
- double separation layer
- covers with a chemical member for increased liability, etc.

The evaluations now in progress at SAFT show lifetimes of seven years can be exceeded. Such accumulators have been used on recent European communication satellites: OTS, MAROTS, METEOSAT.

In a table we show a few mass characteristics and energy characteristics of Ni-Cd batteries developed during space programs.

III. OPERATIONAL AND LIFETIME CONDITIONS OF A BATTERY IN A GEOSTATIONARY ORBIT /5

III.1. Operational Conditions

A satellite placed in a geostationary orbit will penetrate the shadow zone of the Earth two times a year for 45 days. The duration of the eclipses during these periods of 45 days varies between a few minutes to a maximum of 72 minutes. Except for these periods, the satellite is in full view of the Sun. During a longer eclipse, the minimum insolation time is 22.8 hours. One method of charging the batteries takes advantage of this long insolation duration. This leads to a substantial reduction in the power which the solar generator has to deliver. A compromise has to be established between the regime of sufficient charge of the battery and the large dimensions of the solar generator.

In orbit, the batteries have to respond to two kinds of operational conditions:

- a passive role when the satellite is permanently exposed to the Sun (a period of 135 days). The battery has to be maintained in a state of full charge, either by a continuous maintenance current (trickle charge) or by periodic charging.

- An active role during the eclipse period. (45 days) during which the battery is subjected to a daily cycle, and the discharge duration passes through a maximum of 72 minutes.

III.2 Lifetime

The lifetime requirement and the required reliability for providing the success of the mission are determining factors in the design of a Ni-Cd battery.

In this sense, it is important to realize that a substantial improvement in performance can be achieved if the battery is used within its optimum performance range. /6

In this connection, the following recommendations have to be taken into consideration:

- temperature: operational temperatures from 0 to 10°C increase the battery lifetime.

- discharge depth: As a general rule, the charge regime to be used has to be increased, as the discharge depth is increased.

For example at 0°C and 50% of discharge depth, a charge range of C/30 to C/25 is sufficient to provide for the mission requirements. For the same temperature but for a 70% discharge depth, it is necessary to use a higher charge range of between C/25 and C/15.

- Overcharging: It is important to limit the amount of overcharged electricity which reduces lifetime. This can be provided by a telecommand from the ground, either using automatic control such as an ampere-hour meter, a coulometer, or a 3rd electrode.

- Safety: The battery has to be protected against any premature degradation risks: temperatures greater than 35°C or escape of hydrogen inside the battery (for charging, starting at 1.56 to _.60 V per accumulator, or for discharging below 0.0 V). This leads to the use of voltage and temperature protection systems.

In the present definition of Ni-Cd accumulators, by incorporating the rules and precautions mentioned above, one can achieve an improvement in flight performance.

In the following table we give the results obtained up to the present by SAFT in the area of evaluating the lifetime of Ni-Cd accumulators in geostationary orbit.

Normal capacity Ah	Temperature °C	Charge depth %	No. of 24-hr. cycles	Equivalent lifetime year	Observations
26	0	50	1,300	14.4	In progress
26	0	50	1,180	13.1	In progress
26	0	50 max	360	4	In progress, Real eclipse, full Sun simulation
26	0	66 max	360	4	In progress Real eclipse, full Sun simulation
26	0	50 max	945	10.5	In progress Real eclipse simulation in progress
26	0	66	730	8.1	In progress
3.5	25	60	1,500	16.6	In progress
23	10	XX	400	4.4	In progress: available capacity 100T
6	25	XX	950	10.5	In progress: available capacity 60%

XX Complete discharge at each cycle

These results show a lifetime greater than four years for real simulation and greater than 12 years for accelerated tests. This means that we can safely meet the 7-year lifetime requirements for various communication satellites.

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IV. FUTURE PERSPECTIVES

SAFT is pursuing research and development work for improving the lifetime and the reliability of Ni-Cd accumulators and is developing new electrochemical generators such as $Ni-H_2$ and $Ag-H_2$.

As far as the Ni-Cd accumulators are concerned, the main short-term improvement involves better utilization of the product, that is, its use in the area of optimum operating conditions. In this sense, it is primordial to increase the number of performance evaluation tests and the obtained results.

For the long term, the realization of improved lifetime components such as new non-oxidizable separators (polypropylene), or sealed members (non-corrosive) or even new higher performance electrodes, will mean that the lifetime reliability of the Ni-Cd can be improved even more.

Also SAFT is studying and developing new generators such as Ni-H_2 and Ag-H_2, which are primarily of interest because of their higher mass energy content: 55 and 90 Wh/kg respectively, which results in the use of a very light hydrogen electrode and which replaces the cadmium electrodes of Ni-Cd and Ag-Cd. Ni-H_2 and Ag-H_2 are different from the previously mentioned generators primarily because of their operation at higher hydrogen pressures, (30 to 40 bars).

The Ag-H_2 system is in the preliminary study state. We believe that development will be difficult considering the problems to be solved: operation of a silver electrode in a limited electrolyte.

The development of the Ni-H_2 system started at SAFT over two years ago is much more advanced. The first series of accumulators are now being evaluated which will allow one to estimate more accurately their main characteristics and their lifetime performance. This will be valuable in comparison with the performances obtained with the Ni-Cd system.

If their performances confirm, these generators will be used as future energy sources on board communication satellites.

V. CONCLUSION

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Technical improvements made in Ni-Cd accumulators over the last few years associated with the progress in the knowledge of their performance and the optimum utilization conditions, lead us to the consideration of lifetimes greater than 7 years as power sources for communication satellites.

The studies and developments at SAFT with the new systems, especially Ni-H_2, lead us to hope for substantial mass improvements for lifetimes which are comparable or even greater than those achieved with Ni-Cd.