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THE IMPORTANCE OF BATTERIES IN UNMANNED MISSIONS

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Summary

The planetary program has historically used batteries to supply peak power needs for mission specific applications. Any time that additional power has been required in order to meet peak power demands or those applications where only limited amounts of power were required, batteries have always been used. Up until the mid to late 70s they have performed their task admirably. Recently, a growing problem of developing reliable Ni–Cd batteries for long mission and high cycle life applications has been identified. This problem and the role rechargeable batteries will play for future planetary and earth-observing spacecraft, are discussed.

Historical uses of batteries

Planetary

Batteries have always been used whenever there was a need for power in excess of what a standard primary power source could develop, whether it be from solar arrays or radioisotope thermoelectric generators. Primary batteries have been used in probes and other small spacecraft where limited mission life (of the order of hours) is required. Where peak power needs exceed those available from a primary source and are cyclic in nature, then secondary or rechargeable batteries have been used.

Ranger

Ranger was the first spacecraft to use rechargeable batteries. It utilized a Ag–Zn battery to augment the power produced from solar arrays. No battery failures occurred during this set of launches.

Mariner

The Mariner series of spacecraft saw the development of the power system as we know it today. It started with Ag–Zn batteries for Mariners 1 through 7. On Mariner 8, which was launched in May 1971, Ni–Cd batteries were used for the first time. Due to the careful development and preflight testing of these batteries, no failures occurred in the Mariner 7 and 8 power

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systems, which were identical. Similarly, Mariner 9 and 10 flew Ni–Cd batteries successfully.

Viking

Following the successes of the Mariner series of spacecraft, it was decided to develop a lander and an orbiter for Mars observation. In both cases, due to the success of the Ni–Cd batteries of the Mariner series, Ni–Cd batteries were used. Even on the lander, which had a very different environment from that which had been encountered in space, Ni–Cd was the battery of choice. As in the Mariner case, the Ni–Cd batteries performed as expected, with no failures.

Leo/Geo

Planetary is not the only mission set where batteries have a historical base, they have been used successfully in Leo and Geo orbits. The list of these missions is long and marked with great successes due to the careful planning, engineering, and test of the spacecraft subsystems. To list just a few, they include Seasat, the TIROS series, and the whole range of our communications capabilities today.

Recent experiences

Magellan

The mission profile for Magellan is rather benign for the batteries. The battery life is projected at 2100 cycles at a depth of discharge no greater than 40%. This has kept the Magellan batteries well out of the operational area of concern — high cycle count, coupled with large depths of discharge.

GRO

An Earth Observing spacecraft is the first to stress the batteries directly in the operational area of concern. Its high number of cycles has been a major concern to the industry and has warranted careful monitoring of the GRO project. As is well known, the GRO test cells have degraded prematurely using the standard Crane accelerated test. This implies that the batteries may not perform as expected or as required for the GRO mission.

Mars Observer

Noting this failure, the Mars Observer project has similar concerns. The Mars Observer mission profile calls for almost 9000 cycles, well beyond the area of concern. To insure proper operation of the batteries, early coordinated efforts between JPL and the Mars Observer prime contractor, GE–ASD, have led to a new design that both parties feel will meet the mission requirements. Unfortunately, it is not a design that has either been qualified or flown before. Thus, early in the program, test cells will be procured and cycled to see what operational concerns arise. Unfortunately, the project has decided not to continue into mission profile testing.

TOPEX

TOPEX is an Earth Observing mission with a similar type of battery profile. It has a cycle life requirement of 20 000 cycles with a maximum depth of discharge of 15%. While the DOD is not as severe as the Mars Observer condition, the large number of cycles is a real concern. TOPEX and MO have teamed together to perform cell testing in order to verify the battery design, separator material, and lifetime. Until these tests are completed in 1991, no battery decision can be made for either TOPEX or Mars Observer on the final design.

Solutions

Power system engineers around the U.S.A. and the world need a rechargeable battery that is reliable, that has been qualified, and that can meet the strenuous requirements as posed by some of the more advanced scientific missions. Thus, we need to develop batteries that return to the reliability levels seen in the later 70s. To do this, two steps must be taken:

Rigorous quality control

First, a rigorous quality control plan must be developed that oversees the development of new battery designs and insures their reliability. In addition, this plan must take into account the new developments that will occur over the coming years. We must incorporate advances as they become available, but what is not required is the wholesale change of a battery design before it has been proven.

The recent battery workshops held on the Ni–Cd problem have taken the lead in understanding and remedying the problems seen today. These efforts must not stop there, but must continue to improve the reliability and quality of batteries.

Rigorous acceptance testing

In addition to quality control, rigorous acceptance and accelerated life testing must continue on all cells that will fly on strenuous missions. This is a hard pill to swallow in today's world where every dollar has to be justified. However, it is hoped that the recent GRO experience will convince project managers across the U.S.A. to take seriously the advantages of rigorous acceptance and life testing.

Mission profile testing

A caveat to the acceptance test concept is also to perform mission profile testing so that the true nature of the long term performance is understood. Without performing such long term tests, there is no way to predict the true operating characteristics of the battery in flight. In addition, if an anomaly occurs within the battery and/or the power system and one battery is lost, having a battery that has gone through some mission profile testing is invaluable to the understanding of future operational issues. Of particular interest is: how far the battery can be discharged safely, when does it need to be reconditioned, how can the maximum energy be extracted from the battery under the new operating condition?

Conclusions

Ni–Cd batteries have been, and will continue to be, the mainstay of the power system engineer's tools for peak power production. Recent experience has tarnished its once sterling reputation. However, the industry has stood up to this challenge and implemented wide ranging plans to rectify the situation. These efforts should be applauded and supported as new designs and materials become available.

In addition, project managers must become aware of their responsibility to test "their" batteries and insure quality and mission operating characteristics. Without this teamwork, the role of Ni–Cd batteries in the future will diminish, and other batteries, not as optimum for high performance application (low mass and high volume) will take their place.