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AEROSPACE NICKEL–CADMIUM CELL SEPARATOR QUALIFICATION PROGRAM

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Summary

The present space-qualified nylon separator, Pellon 2505 ML, is no longer available for Aerospace nickel–cadmium (Ni–Cd) cells. As a result of this anticipated unavailability, a joint Government program between the Air Force Space Division and the Naval Research Laboratory has been established. Four cell types have been procured with both the old qualified, and the new unqualified, separators. Acceptance, characterization, and life cycling tests are to be performed at the Naval Weapons Support Center. The scheduling and current status of this program are discussed and the progress of testing and available results are projected.

Introduction

The qualified separator material for Aerospace hermetically sealed Ni–Cd cells has been Pellon 2505 ML, produced by the Pellon Corporation. Pellon 2505 ML is a non-woven nylon fabric used for 15 years in the Aerospace industry. In 1976 Pellon Corporation discontinued manufacture of the 2505 ML separator material. The fabrication process incorporated zinc chloride in the bonding of fibers into structures and the process effluent removal required costly treatment. In 1981 General Electric Battery Business Division (GEBBD) informed all users of this separator that continued supply would be unavailable. GEBBD had stored enough of the 2505 ML separator to satisfy cell lot commitments to the end of 1984.

Concern over this issue encouraged Pellon to reactivate their 2505 ML production line. In the interim, however, enough changes in the raw nylon fibers and processing equipment were made that product characteristics were variable. During this period, GEBBD was coordinating its separator physical, mechanical, and chemical parameter needs with Pellon Corporation. A new, nonpolluting process, similar to that used in their German manufacturing plant for 10 years, was introduced and installed in the U.S. Pellon plant to manufacture separator material. GEBBD and Pellon claimed that the new

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separator, 2536, was superior from a uniformity, durability, and performance standpoint. Comparative characteristics and evaluations between the 2505 ML and 2536 separator types appeared encouraging. These preliminary data along with the new separator qualification program definition and structure were published by Milden [1] The essential elements of this program have been updated and are listed below:

○ Air Force Space Division and Naval Research Laboratory procurement of typical military cells from GEBBD.

○ Coordinate with spacecraft battery contractors to insure test plan validity and performance acceptability

○ NWSC/Crane to perform acceptance, characterization, and life cycle testing

○ Generate a consolidated data base for the military customer and the battery contractors/users.

○ Eliminate duplication of effort and qualification costs.

More recent analysis [2] of the Pellon 2536 separator, which was performed at the Aerospace Corp. Laboratories, shows characteristics apparently equivalent, if not superior, to that of the standard Pellon 2505 ML. Table 1 illustrates and compares these pertinent component parameters.

TABLE 1

Separator parametric comparison

Parameter	2505 ML	2536
Process	$ZnCl_2$ stabilized bonded nylon	High temperature inert gas bonded nylon
Fiber diameter	13×10^{-3} in	13×10^{-3} in
Density (g cm^{-3})	1 25	1 25
Electrolyte retention (%)	400	300
Hydrolysis rate (70 - 100 °C)		
*31% KOH	0 5	0 5
*Cd^{2+} added	0 5	0 5

Program structure

The division of cells for test and evaluation is shown in Table 2. Negative electrodes are all silver-treated except the 26.5 A h cells which have Teflon treatment. Positive electrodes consist of the current and standard process design Half of each cell type is constructed with Pellon 2505 ML and half with the proposed new Pellon separator 2536.

Cell specification is not program specific but performance oriented. The specification establishes requirements for manufacturing methods and procedures and defines processes and fabrication methods at a point in time for a Ni–Cd cell type.

TABLE 2

Cell test distribution

Capacity (A h)	Cell type designation	Test matrix	GE destruct	Quantity/end use		Characterization
				Wet storage	Dry storage	
26 5	42B030AB10/14	30	1	2	2	4
34	42B034AB02/03	30	1	2	2	2
35	42B035AB02/13	30	1	2	2	4
50	42B050AB24/28	45	1	5	3	4
		135	4	11	9	14

Cell testing and evaluation

After cells are received at NWSC/Crane, they undergo three separate but consecutive tests. These are:

(i) Acceptance

(ii) Characterization

(iii) Life cycling

(i) Acceptance testing at Crane enables performance comparison to acceptance test data from GEBBD and provides a basis for cell matching and pack fabrication.

(ii) Characterization testing is performed on all cell types after being subjected to random vibration to simulate the launch environment. Following vibration the cells will be placed in restraining plates with temperature monitoring. Following a conditioning cycle and ten capacity stabilization cycles the cells will undergo voltage characterization at various charge current rates ($C/2$ to $C/80$) and temperatures (30 °C to −10 °C) These characterization tests will differentiate between the two separator types according to the electrochemical mass transport capabilities. In other words, the existing voltage–temperature charge curves will be requalified for the Pellon 2536 separator in relation to the existing Pellon 2505 ML.

As seen in Table 2, cell types will also be stored in both the activated (wet storage) and unactivated (dry storage) states, as elapsed test time controls for comparative analysis.

(iii) The life cycling test matrix consists of 135 cells and is illustrated in Table 3 with the test details shown in Table 4.

The cells are assembled into five- and ten-cell packs following a pack fabrication procedure which is weighted with eleven parameters from the NWSC/Crane acceptance tests. For both orbits, two test levels are imposed to simulate both actual and accelerated performance behavior. For the low earth orbit (LEO) only, the higher temperature and greater depth of discharge is used to enhance any performance level limitations for either

TABLE 3

Test matrix

Orbit	DoD (% Actual)	Charge control	Test temp (°C)	2505 ML Separator (A h)				2536 Separator (A h)			
				50	34	35	26 5	50	34	35	26 5
LEO	25	V–T Taper	0		5		5	5	5		5
LEO	40	V–T Taper	20		10		10	10	10		10
GEO Accel	75	V–T Taper	0	5		5		5		5	
GEO Accel	75	V–T Taper	20	10		10		10		10	

TABLE 4

Life cycle details

Test	Capacity		Current		V/T	C/D
	Nameplate Est	Actual	Discharge (A)	Charge	Curve	Range
LEO, 25%, 0 °C	26 5AH	30AH	13 4	$C/3$	5	1 00 - 1 08
	34	41	18 3	$C/2$	5	1 00 - 1 08
	50	50	22 3	$C/3$	5	1 00 - 1 08
LEO, 40%, 20 °C	26 5	30	21 4	$C/2$	5	1 00 - 1 08
	34	41	29 3	$C/2$	5	1 00 - 1 08
	50	50	35 7	$C/2$	5	1 00 - 1 08
					Taper current (A)	
GEO, 75%, 0 °C	35AH	37AH	23 1	$C/10$	5	0 5 - 0 3
	50	50	31 3	$C/10$	5	0 75 - 0 5
GEO, 75%, 20 °C	35	37	23 1	$C/10$	5	0 5 - 0 3
	50	50	31 3	$C/10$	5	0 75 - 0 5

separator. The geostationary orbit (GEO) is considered accelerated, since no trickle charging, simulating conditions between eclipse seasons, is imposed. The two GEO temperature levels simulate actual use environments. The LEO orbital simulation consists of a 33.6 min (0 56 h) eclipse and a 67 2 min (1.12 h) sunlight period. The cycling is continuous with no scheduled capacity measurements or reconditioning The preselected, temperature-compensated voltage limit (V/T-limit) is chosen to maintain a charge-to-discharge ratio of 1.00 - 1.08, including the taper current The GEO orbital simulation consists of a typical 42 day eclipse season and, following each season, the packs are trickle charged at $C/60$ for two days. Each pack is to be reconditioned to 0.75 V average pack voltage for approximately ten days following the trickle charge. Recharge prior to the next season is at the $C/4$ rate. Within an eclipse season, cell packs are charged at the $C/10$ rate to a V/T-limit, followed by a taper current charge for the remainder of the eclipse day.

Status and schedule

The joint Air Force/Navy separator qualification program has been funded though 1990. A chronological list of key program milestones are listed below:

- Procurement specification — Sep 1983
- Contract with GEBBD for procurement of 154 Ni–Cd cells — Mar 1984
- Amend contract to add 19 additional 50 A h cells — Aug 1984
- Contract modifications and material review — Jun 1985
- 30 and 34 A h cells consigned to NWSC/Crane — Jun 1985
- Detailed test plan — Sep 1985
- 35 and 50 A h cells consigned to NWSC/Crane — Nov 1985

The current status and projected test schedule at NWSC/Crane is illustrated in Table 5 on a time-line diagram.

At this time, as can be seen in Table 5, the first of the four cell types, 42B034AB02 and 03 (34 A h cells), has completed acceptance testing at

TABLE 5

Current and projected schedule

	1985				1986				
	Sept	Oct	Nov.	Dec	Jan	Feb	Mar	Apr	May
Acceptance tests									
30 A h		X——	——X						
34 A h	X——X								
35 A h				X——	——X				
50 A h				X——X					
Characterization									
30 A h						X——	——X		
34 A h						X——X			
35 A h							X——	——X	
50 A h							X——	——X	
Life cycling tests									
30 A h			X——	——	——	——	——	——	——
34 A h			X——	——	——	——	——	——	——
35 A h					X——	——	——	——	——
50 A h					X——	——	——	——	——
Test reports					X			X	

Crane. The data demonstrate comparable and nominal capacities for both the Pellon 2505 ML and 2536 separator types in the 25, 10, and 0 °C capacity and overcharge acceptance tests. In addition, the typical roll-over in charge voltage was observed for both cell types, indicating good negative plate electrochemical behavior. Maximum charge voltage for the Pellon 2536 cells, however, is attained earlier in the allotted time for charge than for the Pellon 2505 ML The significance of this will not be known until the characterization tests are completed and the life cycling initiated.

Future

Life cycle testing is ensured for almost five years, since all cell types are projected to have completed their acceptance tests at NWSC/Crane by February, 1986.

The structure of the separator test program is designed to provide a high degree of confidence based on long term testing exposing any subtle differences far in advance of actual flight usage. As a result of forced utilization of the new Pellon 2536 separator for near-term cell lot buys, the separator qualification test program has received the support and encouragement of many spacecraft program offices. Preliminary test evaluation data to demonstrate comparable performance and acceptability of the new material with that of the Pellon 2505 ML will not be available, however, with any degree of confidence and reliability until the end of 1986. This will obviously impact decisions to purchase Ni–Cd cells with the new Pellon 2536 separator for spacecraft flight use

Conclusion

The Ni–Cd cell separator qualification program will provide a common data base for the comparison of performance characteristics of cells with Pellon 2505 ML and identical cells with Pellon 2536 in concurrent tests. Preliminary life cycle data at more severe temperatures and discharge depths will be available by the end of 1986 to verify cell performance with the new Pellon 2536 Close to five years of long-term, real-time cell cycling is funded to verify cell performance and acceptability of the Pellon 2536 separator Joint Air Force and Navy funding to one centralized facility, NWSC/Crane, will produce a statistically more valid data base at an overall lower cost by minimizing individual spacecraft program office evaluation, management, coordination, and testing. This will enhance the value of the data base by enabling direct comparison of the two cell types with different separator components

Test reports will be issued after each cell type acceptance test and after each characterization test. In addition, NWSC/Crane will distribute annual cycle life test reports and trends analysis at selected times throughout the year. These reports will be made available on request to NWSC/Crane and will be distributed in normal fashion subject to approval from the Air Force and Navy.

References

1 M J Milden and J Harkness, *Proc Nineteenth Intersoc Energy Conversion Eng Conf*, *1* (1984) 108, AIAA, New York

2 Badcock, The Aerospace Corp , personal communication, Oct 31, 1985, to be published.