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DEPARTMENT OF THE NAVY
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10 DEC 1969

From: Commanding Officer, Naval Ammunition Depot, Crane, Indiana
To: National Aeronautics and Space Administration, Goddard Space Flight Center (Code 716.2, Mr. T. J. Hennigan), Greenbelt, Maryland 20771

Subj: Progress Report on National Aeronautics and Space Administration Space Cell Test Program (3 copies)

Ref: (a) Goddard Space Flight Center Purchase Order S-23404-G

Encl: (1) Description of Tests
(2) Status of Tests as of 31 October 1969

1. In compliance with reference (a), enclosures (1) and (2) are forwarded for information and retention.

C. G. LYNCH
By direction

Copy to:
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FACILITY FORM 602

1. Burgess-Borden Separator Test:

a. Burgess-Borden, 10 ampere-hour, silver-zinc cells are being tested to evaluate the performance of various separator materials. The performance of cells with the various types of separator material is compared to that of control cells with PUDO type separator material. The alphanumeric symbols designating the various types of separator material are as follows:

(1) C-3, B-3, 9107-4, 9107-5, 9107-8, 9107-12, 9107-13, 9107-14, 9017-15 and 5-9107-23.

b. Preparation:

(1) Vacuum fill the cells with 30 or 40 percent KOH, as specified, and place on stand for 72 hours before testing.

(2) Adjust the electrolyte in all cells to the tops of the plates at the end of the charge cycle.

(3) Conduct all tests at 25° C (room temperature).

c. Test Procedure:

(1) Subject the cells to a series of three preconditioning cycles as follows:

(a) Cycles 1 and 2: Charge at the c/20 rate (500 milliamperes) until cells receive 120 percent of rated capacity (24 hours); then following a 16-hour stand, discharge the cells individually at the c/5 rate (2 amperes) to an end voltage of 1.30 volts. Allow cells to stand in a discharged condition from 1 to 5 hours before recharging.

(b) Cycle 3: Charge at the c/20 rate (500 milliamperes) until cells receive 120 percent of rated capacity (24 hours); then following a 16-hour stand, discharge the cells individually at the c/1 rate (10 amperes) to an end voltage of 1.30 volts.

(2) Following the preconditioning cycles, test the cells under one of the following procedures:

(a) Constant-Potential Cycling Test (99 Cells; 12 Packs):

1. Charge at the c/20 rate (500 milliamperes) until the cells receive the specified 120 percent of the preceding discharge.

2. Subject the cells to continuous discharge-charge cycling as follows:

a. Individually discharge the cells at the c/5 rate (2 amperes) to a terminal voltage of 1.30 volts; at which time remove the cell from the circuit and record the discharge time.

b. Allow the cells to stand in the discharged condition from 1 to 5 hours.

c. Charge the cells for 30 hours at the c/20 rate (500 milliamperes) to a voltage limit of 1.97 volts per cell, average.

d. Allow the cells to stand in a charged state for 2 hours before recycling.

(b) Constant Current Test (45 Cells; 5 Packs):

1. Charge the cells at the c/20 rate (500 milliamperes) to the specified 105 or 120 percent of the preceding discharge.

2. Subject the cells to continuous discharge-charge cycling as follows:

a. Individually discharge the cells at the c/5 rate (2 amperes) to a terminal voltage of 1.30 volts; at which time remove the cell from the circuit and record the discharge time.

b. Allow the cells to stand in the discharged state from 1 to 5 hours.

c. Charge the cells at the c/20 rate (500 milliamperes) to the specified 105 or 120 percent of the preceding discharge.

d. Allow the cells to stand in the charged state for 2 hours before recycling.

(c) Charged Stand Test (59 Cells; 10 Packs):

1. Charge the cells at the c/20 rate (500 milliamperes) to the specified 120 percent of the preceding discharge.

2. Allow the cells to stand in the charged condition for 2 hours.

3. Subject the cells to continuous discharge-charge cycling as follows:

a. Individually discharge the cells at the c/5 rate (2 amperes) to a terminal voltage of 1.30 volts; at which time remove the cell from the circuit and record the discharge time.

b. Allow the cells to stand in the discharged state from 1 to 5 hours.

c. Charge the cells at the c/20 rate (500 milliamperes) to the specified 120 percent of the preceding discharge.

d. Allow the cells to stand in the charged condition for 30 days (open circuit) before recycling.

d. Recording of Test Results:

(1) Discharges: Following open circuit cell voltage readings, record the cell voltages and current at 1 minute, 15 minutes, 30 minutes, and every 30 minutes thereafter to the specified cutoff voltage.

(2) Recharges: Following open circuit cell voltage readings, record the cell voltages 1 minute after start of charge and hourly thereafter to completion of charge.

(3) Charged Stand Test: Following recharge, open circuit cell voltages were recorded daily.

2. Open Circuit and Overcharge Tests:

a. The purpose of this test is to gather as much information as possible on the storage of charged cells on open circuit or continuous charge conditions. Since it is not a failure type test, no cells will be considered as failed unless for some internal shorting problem. Ten Sonotone, 3.5 ampere-hour, nickel-cadmium cells were subjected to the open circuit test, and 10 to the overcharge test. These cells were subjected to the series of acceptance tests upon their receipt and following 1 year of their respective open circuit or overcharge tests. They will be subjected to the series of acceptance tests following each successive year of their respective tests. After the first and succeeding annual series of acceptance tests; analyze the cell from each group which shows the greatest loss of capacity.

b. Acceptance Test Procedure:

(1) Capacity Test: Subject the cells to a series of three capacity checks as follows:

(a) Charge the cells in series for 16 hours at the c/10 rate (350 milliamperes).

(b) Allow cells to stand for 1 hour before discharging.

(c) Discharge the cells individually at the c/2 rate (1.75 amperes) to cutoff of 1.00 volt per cell.

(d) Record cell voltages every hour on charge, and every 10 minutes on discharge.

(2) Cell Short Test: Following completion of the third capacity check discharge:

(a) Load each cell with a resistor of a value giving a c/1 to c/5 (3.5 amperes to 700 milliamperes) discharge rate.

(b) Allow the cells to stand for 16 hours with the resistor acting as a shorting device.

(c) Remove resistors and allow cells to stand on open circuit for 24 hours.

(d) Record cell voltages hourly.

(3) Immersion Seal Test:

(a) Place the cells under water in a bell jar.

(b) Reduce the pressure in the bell jar to 10 inches of mercury and hold for 3 minutes.

(c) During this 3-minute period scrutinize the cells for a steady stream of bubbles, thereby indicating a leak around a seal or weld.

(4) Overcharge Test:

(a) Charge the cells in series at each of three rates for 48 hours as follows:

1. c/20 (175 milliamperes).

2. c/10 (350 milliamperes).

3. c/5 (700 milliamperes).

(b) Record the cell voltages hourly.

(c) Discontinue charging of any cell that exceeds 1.50 volts.

(5) Internal Resistance Test:

(a) At the completion of the overcharge test return the cells to the c/20 (175 milliamperes) charging rate, $I_{c/20}$.

(b) While charging at this rate, pulse the charging current at the c rate (3.5 amperes), I_c, for 5 to 10 seconds.

(c) Record the cell voltage, V_1, immediately prior to the pulse, and the cell voltage, V_2, 5 milliseconds after initiation of the pulse.

(d) Calculate the internal resistances of the cells according to:

$$R = \frac{V_2 - V_1}{I_c - I_{c/20}}$$

(6) Repeat the immersion seal test.

c. Open Circuit Stand and Overcharge Test Procedures:

(1) Open Circuit Stand:

(a) Charge the cells in series at the c/10 rate (350 milliamperes) for 16 hours.

(b) Place cells in individual holders, on a shelf for 1 year.

(c) Record the cell voltages weekly.

(2) Overcharge Test:

(a) Charge the cells in series at the c/10 rate (350 milliamperes) for 16 hours.

(b) Charge the cells in series at the c/100 rate (35 milliamperes) for 1 year.

(c) Record the cell voltages weekly.

(3) Following completion of each year of the open circuit stand test or the overcharge test:

(a) Discharge the cells individually to the specified cutoff of 1.00 volt for capacity measurement.

(b) Again subject the cells to the series of acceptance tests.

3. IMP E, #10:

a. One 13-cell, Yardney, 10 ampere-hour, silver-cadmium battery is being tested under environmental conditions simulating those encountered by the EXPLORER XXXV space vehicle. The 13 cells are connected in series and encased in a metal container with epoxy resin.

b. Initial Charge:

(1) Upon receipt of this battery the cells were discharged to zero volts through 1-ohm resistors placed across the voltage monitoring leads of the individual cells. The battery was then charged at 600 milliamperes until the voltage of any one cell reached 1.55 volts.

c. Cycling Procedure:

(1) Cycling under simulated conditions was accomplished by placing the battery in a vacuum chamber which in turn was placed in a temperature chamber.

(a) The pressure inside the vacuum chamber was maintained at approximately 20 microns of mercury.

(b) The temperature chamber was maintained at 25° C for the first 7 days of cycling, after which the temperature was reduced at a rate of 5° C per hour to 5° C and maintained at that temperature.

(2) The discharge-charge cycling consists of half hour discharges followed by 11-hour charges. The battery is required to deliver constant power during which the discharge current ranges from approximately 2.5 amperes at the beginning to approximately 2.8 amperes near the end of discharge.

(3) Part of the current from the power supply, used to charge the battery, is required by the electronic instrumentation simulating the EXPLORER XXXV spacecraft. The maximum current available from this power supply is 3 amperes. The balance of the current drawn from the power supply is used to charge the battery. Charging of the battery is controlled by a two-step regulator, with the initial charging current approximately 600 milliamperes. When the battery voltage reaches 19.6 volts (1.51 volts per cell) the charging current starts to decrease, and when it decreases to 100 milliamperes, the two-step regulator is automatically reset to hold the battery voltage at 18.3 volts (1.41 volts per cell).

(4) The battery voltage, cell voltages, battery current, battery temperature, and ambient pressure are recorded at the beginning and end of discharges and charges. Every 20 cycles these parameters are recorded every 10 minutes on discharge and hourly on charge. Specific voltages in the electronic instrumentation simulating the spacecraft are measured and recorded via the battery evaluation panel at least once every 24 hours.

4. IMP F, #4:

a. One 13-cell Yardney, 3.0 ampere-hour, silver-cadmium battery is being tested under temperature and load conditions simulating those encountered by one of the EXPLORER series space vehicles. The 13 cells are connected in series and encased in a metal container with epoxy resin.

b. Initial Charge:

(1) The cells were initially discharged for 16 hours through 1-ohm resistors placed across the voltage monitoring leads of the individual cells. The battery was then charged at 300 milliamperes until the voltage of any cell reached 1.55 volts. Following this the cells were discharged at 2.5 amperes until the average cell voltage was 0.9 volt. The cells then received another charge at 300 milliamperes until the voltage of any cell reached 1.55 volts.

c. Cycling Procedure:

(1) Prior to undergoing repetitive discharge-charge cycling, this battery was placed in a temperature controlled chamber which was held at 25° C. The cells were then discharged at 2.5 amperes for 20 minutes, after which they were charged at 2.5 amperes until the battery voltage reached 19.6 volts (1.51 volts per cell). (Charging of the battery is controlled by a two-step regulator.) When the battery voltage reached 19.6 volts (1.51 volts per cell) the charging current decreased. When the current decreased to 50 milliamperes the two-step regulator automatically reset to hold the battery voltage at 18.3 volts (1.41 volts per cell). For the following 14 days the cells received charging current necessary to maintain the battery voltage at 18.3 volts (1.41 volts per cell). On the 15th day the ambient temperature of the cells was reduced from 25° C to 8° C at the rate of 4° C per hour. Charging was continued at a rate that maintained the on-charge voltage at 18.3 volts until the 20th day.

(2) On the 20th day with the ambient temperature of the cells still at 8° C, the first discharge-charge cycle was started. It had a duration of 20 days, beginning with a discharge period of 2 minutes followed by charging for the balance of the 20-day period. After the 40th day, the discharge-charge cycle periods were 4 days. The duration of the discharge periods increased from 5 minutes at the first 4-day cycle to 23 minutes at the 13th through the 16th 4-day cycle and decreased to 8 minutes at the 23rd 4-day period. The discharge current was 2.5 amperes.

(3) Since the discharge-charge cycle period after the 40th day was always 4 days, and the duration of the discharge period varied, the duration of the charge period varied accordingly. Charging was at 2.5 amperes until the battery reached a voltage of 19.6 (1.51 volts per cell). When the battery voltage reached 19.6 volts (1.51 volts per cell) the charging current decreased. When the current decreased to 50 milliamperes, the two-step regulator was automatically reset to 18.3 volts (1.41 volts per cell) and maintained at that value for the balance of the charge period.

5. Synchronous Orbit 10HR16(S)-1 #4:

a. Ten Yardney, 16 ampere-hour, sealed, silver-zinc cells were tested under conditions similar to those aboard a synchronous orbit satellite.

b. Initial Cycle:

(1) Initially the cells were discharged individually, through 1-ohm resistors, to 0.6 volt per cell. They were then charged in series at 700 milliamperes to an average voltage of 1.98 volts per cell (19.8 total volts). Charging was to be terminated prior to reaching 19.8 volts if the voltage of any one cell exceeded 2.0 volts. The cells were then discharged at 5.0 amperes for 1 hour followed by a charge for 23 hours at 500 milliamperes until the voltage reached 19.8 volts. (Charging of the battery is controlled by a two-step regulator.) When the battery voltage reached 19.8 volts (1.98 volts per cell) the charging current decreased. When the current decreased to 100 milliamperes the two-step regulator automatically reset to hold the battery voltage at 18.6 volts (1.86 volts per cell) for the balance of the charge period. The battery was left on continuous float at 1.86 volts per cell for an additional 59 days.

c. Cycling Procedure:

(1) During the periods from the 61st through the 100th day and from the 241st through the 280th day of orbiting, these cells were subjected to 24 hour discharge-charge cycling to simulate the so called 40-day shadow periods experienced by the battery aboard a synchronous orbit satellite.

(2) The duration of the discharge of the first day of each 40-day shadow period was 0.2 hour. The discharge time for the succeeding days up through the 16th day was increased by uniform increments to 1.2 hours and held at 1.2 hours for each of the succeeding 8 days. Then during the last 16 days of each 40-day shadow period, the daily discharges were decreased by uniform increments to 0.2 hour. The discharges were at 5.0 amperes.

(3) Charging was at 800 milliamperes until the total voltage reached 19.8 volts at which time charging was automatically crossed over to constant potential. When the charge current decreased to 100 milliamperes, the constant potential charge was automatically reset to 18.6 volts (1.86 volts per cell) and maintained at that value for the balance of each charge period.

(4) While cycling during the shadow periods, the total cell voltage and current were recorded on strip chart recorders. In addition, the individual cell voltages, the total voltage and the current were measured with a digital voltmeter and recorded. These readings were taken three to seven times during discharges, and hourly during the charge periods.

(5) Between the shadow periods, the cells were on continuous charge for 140 days and received sufficient current from the two-step

regulator to maintain the total cell voltage at 18.6 volts. During this time, the individual cell voltages, the total voltage and the current were measured with a digital voltmeter daily and recorded.

6. Yardney Separator and Plate Test:

a. The purpose of this test was to obtain data on 30 Yardney, 12 ampere-hour, specially constructed silver-zinc cells for National Aeronautics and Space Administration, Goddard Space Flight Center.

b. These cells are assembled into six 5-cell packs, three of which consist of sealed cells with pressure gages, and the remaining three packs consist of unsealed cells. One pack of each group contained RAI 2.2XH series 2 separators; another pack of each group had Teflon in the negatives with Emulphogene in the electrolyte as an additive; and the third pack in each group had negative plates with extended edges. These cell constructions are listed below:

SEALED CELLS WITH PRESSURE GAGES

Series	Pack No.	Cells Number
K969	1	68, 70 through 73 (with RAI 2.2XH series 2 separators)
K969	2	55 through 59 (with Teflon negatives and Emulphogene)
K1100	3	49 through 53 (with negative edges extended)

UNSEALED CELLS

Series	Pack No.	Cells Number
K969	4	74 through 78 (with RAI 2.2XH series 2 separators)
K969	5	60, 61, 62, 64 & 65 (with Teflon negatives and Emulphogene)
K1100	6	54 through 58 (with negative edges extended)

c. Each of the cells was initially discharged through a 1-ohm resistor to 1.0 volt. Then the cells received two consecutive charge-discharge cycles, each consisting of an 800 milliampere constant current charge followed by a constant current discharge at 3.0 amperes. Cells were removed individually from the charge circuit as each reached 2.0 volts, and were likewise removed from the discharge circuit as each reached 1.30 volts.

d. The cells received continuous charge-discharge cycling at room temperature. Charging of the 15 (3 packs) sealed cells with pressure gages was at 800 milliamperes until the first cell in each pack reached 1.97 volts, at which time the current was reduced to 100 milliamperes and maintained at that level for the balance of the 30-hour charge period. The 15 (3 packs) unsealed cells were charged at 800 milliamperes until 120 percent of the previous discharge capacity was returned to each cell. The cells were allowed to stand on open circuit for a minimum of 2 hours between end of charging and beginning of discharge. Both groups of cells

(sealed and unsealed) were then discharged at 3.0 amperes, and each cell in turn, when its voltage decreased to 1.30 volts was removed from the circuit. At the end of each discharge, the cells were placed on open circuit for 1 to 5 hours before being placed on the charge portion of the next cycle. Individual cells were removed from test upon delivering less than 4.0 ampere-hours on the discharge portion of the cycle.

e. Pack voltages, cell voltages and current were measured and recorded every 15 minutes during discharge and every hour during charge. Pressure was recorded hourly.

7. Polymerized Neoprene Seal Overcharge Test:

a. Five Gulton, 3.5 ampere-hour, nickel-cadmium cells were tested to evaluate the performance of their polymerized neoprene seals. Prior to being put on overcharge these cells received the standard acceptance tests.

b. Acceptance Test Procedure:

(1) Capacity Test: Subject the cells to a series of three capacity checks as follows:

(a) Charge the cells for 16 hours at the c/10 rate (350 milliamperes).

(b) Allow cells to stand for 1 hour before discharging.

(c) Discharge the cells individually at the c/2 rate (1.75 amperes) to cutoff of 1.00 volt per cell.

(d) Record cell voltages every hour on charge, and every 10 minutes on discharge.

(2) Cell Short Test: Following completion of the third capacity check discharge:

(a) Load each cell with a resistor of a value giving a c/1 to c/5 (3.5 amperes to 700 milliamperes) discharge rate.

(b) Allow the cells to stand for 16 hours with the resistor acting as a shorting device.

(c) Remove resistors and allow cells to stand on open circuit for 24 hours.

(d) Record cell voltages hourly.

(3) Immersion Seal Test:

(a) Place the cells under water in a bell jar.

(b) Reduce the pressure in the bell jar to 10 inches of mercury and hold for 3 minutes.

(c) During this 3-minute period scrutinize the cells for a steady stream of bubbles, thereby indicating a leak around a seal or weld.

(4) Overcharge Test:

(a) Charge the cells at each of three rates for 48 hours as follows:

1. c/20 (175 milliamperes).

2. c/10 (350 milliamperes).

3. c/5 (700 milliamperes).

(b) Record the cell voltages hourly.

(c) Discontinue charging of any cell that exceeds 1.50 volts.

(5) Internal Resistance Test:

(a) At the completion of the overcharge test return the cells to the c/20 (175 milliamperes) charging rate, $I_{c/20}$.

(b) While charging at this rate, pulse the charging current at the c rate (3.5 amperes), I_c, for 5 to 10 seconds.

(c) Record the cell voltage, V_1, immediately prior to the pulse, and the cell voltage, V_2, 5 milliseconds after initiation of the pulse.

(d) Calculate the internal resistances of the cells according to:

$$R = \frac{V_2 - V_1}{I_c - I_{c/20}}$$

(6) Repeat the immersion seal test.

c. Following the acceptance tests the cells shall be put on continuous charge at the c/10 rate (350 milliamperes) to test the ability of polymerized neoprene seals to withstand continuous overcharging. The cell voltages, pack voltage and current are measured and recorded at 4-hour intervals. The cells are visually checked for leaks three times a day.

8. S cubed; 6902-6YS3TB, Batteries 1, 2 and 3:

a. Each Yardney, 3.0 ampere-hour, silver-cadmium battery, containing five cells in series, is encased in a metal container filled with epoxy resin. The batteries are being tested under the following procedures.

b. Batteries No. 1 (0° C) and No. 3 (25° C) shall operate under an 8-hour cycle consisting of a two level voltage charge for 7 hours and 20 minutes, and a discharge for 40 minutes. Charging shall be at 200 ma until the high level voltage limit of 9.0 volts is reached--at which time the charge current decreases to maintain 9.0 volts. When the charge current reaches 40 ma the voltage limit is reduced to 8.4 volts. When the low level voltage limit is reached before the end of the charging period, the charge current shall be reduced to zero.

c. Battery No. 2 (0° C) shall be tested in the following manner. It shall operate under an 8-hour cycle consisting of a two level voltage charge for 7 hours and a discharge for 1 hour. Charging shall be at 200 ma until the high level voltage limit of 9.13 volts is reached--at which time the charge current decreases to maintain 9.13 volts. When the charge current reaches 40 ma the voltage limit is reduced to 8.4 volts. When the low level voltage limit is reached before the end of the charging period, the charge current shall be reduced to zero.

d. The batteries shall be operated for 200 continuous cycles of discharge and charge or to the cutoff of 5.4 volts, whichever comes first.

e. Battery voltage, cell voltages, current and temperature are recorded on a strip chart recorder every third cycle.

f. The low level voltage has been increased from 8.40 volts to 8.53 volts for battery number 1 at 0° C; 8.50 volts for battery number 2 at 0° C; and 8.55 volts for battery number 3 at 25° C.

9. S cubed; 5XYS5(S) C-3A, Batteries 1 and 2 from Group 80-1:

a. Each Yardney, 3.0 ampere-hour, silver-cadmium battery contains five cells connected in series and is encased in a metal container filled with epoxy resin. The batteries were tested under the following procedures.

b. One battery of five cells was cycled (charged and discharged repetitively) at -10° C and the other battery was cycled at 25° C. The total cycle period was 7.5 hours, consisting of a charge for 6 hours and 46 minutes at 200 milliamperes to a voltage limit, followed by a discharge of 44 minutes. The on-charge voltage limit for the battery cycling at -10° C was 7.75 (1.55 volts per cell); and for the battery charging at 25° C was 7.50 (1.50 volts per cell). During the discharge periods, the discharge rate for the first 34 minutes was 1.0 ampere; and during the last 10 minutes was 2.5 amperes.

c. Battery voltages, cell voltages and currents were measured and recorded at the beginning and end of each charge and discharge of each cycle; and on each 15th cycle, these parameters were also recorded at the 10, 20, 33 and 35 minute points during discharge and hourly during charge.

10. ESB-Borden Separator Evaluation Test:

a. Sixty ESB-Borden, 10 ampere-hour, silver-zinc cells are being tested to evaluate the performance characteristics of various separator materials developed by the Borden Chemical Company. The plates of each group of 15 cells are insulated with one of the following types of separator materials or combination thereof and are designated as types 9107-27; 9107-29; 9107-27/29; and 9107-C3.

b. .Preparation:

(1) The cells were vacuum filled with 40 percent KOH which was supplied by ESB, and then placed on stand for 72 hours before testing.

(2) All tests were conducted at 25° C (room temperature).

c. Initial Conditioning Cycle Procedure:

(1) The first and second cycles consisted of:

(a) Charges at the c/20 rate (500 milliamperes) for 24 hours to give an input of 120 percent of the manufacturer's rated capacity. At the end of each charge, the electrolyte level was adjusted to the top of the plates using 40 percent KOH electrolyte supplied by ESB.

(b) Then following a 16-hour stand, the cells were individually discharged at the c/5 rate (2.0 amperes) to an end voltage of 1.3 volts. The cells were allowed to stand 1 to 5 hours before recharging.

(2) The third cycle consisted of:

(a) A charge at the c/20 rate (500 milliamperes) for 24 hours to give an input of 120 percent of the manufacturer's rated capacity. At the end of charge, the electrolyte level was adjusted to the tops of the plates using 40 percent KOH electrolyte supplied by ESB.

(b) Then following a 16-hour stand, the cells were individually discharged at the c/1 rate (10.0 amperes) to an end voltage of 1.3 volts.

(3) The fourth charge was at the c/20 rate (500 milliamperes) for 24 hours to give an input of 120 percent of the manufacturer's rated capacity. At the end of charge, the electrolyte level was adjusted to the top of the plates using 40 percent KOH electrolyte supplied by ESB.

d. Constant Potential Charge Test (5 cells of each separator type or combination used):

(1) The cells were allowed to stand on open circuit for 16 hours following the recharge in paragraph 10.c.(3).

(2) They were then discharged individually at the c/5 rate (2.0 amperes) to a terminal voltage of 1.3 volts and, then allowed to stand on open circuit from 1 to 5 hours before recharging.

(3) These cells were then charged at a constant potential of 2.0 volts per cell average for 30 hours with a maximum current of 500 milliamperes. Following the charge, the cells were allowed to stand for 2 hours during which time electrolyte (40 percent KOH) was added as necessary to maintain the electrolyte level at the top of the plates.

(4) These cells were cycled continuously as outlined in paragraphs 10.d.(2) and 10.d.(3) until each cell failed to deliver a minimum of 4.0 ampere-hours.

e. Constant Current Charge Test (5 cells of each separator type or combination used):

(1) The cells were allowed to stand on open circuit for 16 hours following the recharge in paragraph 10.c.(3).

(2) They were then discharged individually at the c/5 rate (2.0 amperes) to a terminal voltage of 1.3 volts, and then allowed to stand on open circuit from 1 to 5 hours before recharging.

(3) The cells were then charged at a constant current rate of c/20 (500 milliamperes) until 120 percent of the capacity each cell delivered on the previous discharge was returned. Following completion of charge of the last cell, the cells were allowed to stand in the charged condition for 2 hours, during which time electrolyte (40 percent KOH) was added as necessary to maintain the level at the top of the plates.

(4) These cells were cycled continuously as outlined in paragraphs 10.e.(2) and 10.e.(3) until each cell failed to deliver a minimum of 4.0 ampere-hours.

f. Charged Stand Test (5 cells of each separator type or combination used):

(1) The cells were allowed to stand on open circuit for 16 hours following the recharge in paragraph 10.c.(3).

(2) These cells were then discharged individually at the c/5 rate (2.0 amperes) to a terminal voltage of 1.3 volts, and then allowed to stand on open circuit from 1 to 5 hours before recharging.

(3) The cells were then charged at a constant current rate of c/20 (500 milliamperes) until 120 percent of the capacity each cell delivered on the previous discharge was returned. Near the end of charge, electrolyte (40 percent KOH) was added as necessary to maintain the level at the top of the plates. The cells were allowed to stand in the charged condition for 30 days.

(4) These cells were cycled continuously as outlined in paragraphs 10.f.(2) and 10.f.(3) until each cell failed to deliver a minimum of 4.0 ampere-hours.

g. Recording of Test Results:

(1) Discharges: Following the open circuit cell voltage readings, the cell voltages and current were recorded at 1 minute, 15 minutes, 30 minutes, and every 30 minutes thereafter to the specified cutoff of 1.3 volts per cell.

(2) Recharges: Following the open circuit cell voltage readings, the cell voltages were recorded 1 minute after start of charging and hourly thereafter to completion of charge.

(3) 30-Day Stand: Following the recharge, the open circuit cell voltages were recorded daily.

h. The first cell in each 5-cell test group to fail was sent to: ESB, Inc., Carl F. Norberg Research Laboratory (Mr. Jack Kelly), Yardley, Pennsylvania 19067.

11. ESB Separator Test:

a. ESB, 10 ampere-hour, silver-zinc cells are being tested to evaluate the performance characteristics of various separator materials. The plates of each group of 15 cells are insulated with one of the following types of separator material, or combination thereof, and are designated as follows:

SK9211-1	Control group with 193 Pudo separator material
SK9211-2	RAI Permion 1770C separator material
SK9211-3	RAI Permion 2290 separator material
SK9211-4	RAI Permion 2291 separator material
SK9211-5	RAI Permion 2291 separator material
SK9211-6	193 Pudo separator material
SK9211-7	RAI Permion 2291 separator material
SK9211-8	RAI Permion 2291 separator material
SK9211-9	RAI Permion 2291 and RAI Permion 116 separator material
SK9211-10	RAI Permion 2291 and RAI Permion 2290 separator material
SK9211-11	RAI Permion 2291 separator material.

b. Preparation:

(1) The cells were vacuum filled with 40 percent KOH which was supplied by ESB, and then placed on stand for 72 hours before testing.

(2) All tests were conducted at 25° C (room temperature).

c. Initial Conditioning Cycle Procedure:

(1) The first and second cycles consisted of:

(a) Charges at the c/20 rate (500 milliamperes) for 24 hours to give an input of 120 percent of the manufacturer's rated capacity. At the end of each charge, the electrolyte level was adjusted to the top of the plates using 20 percent KOH electrolyte supplied by ESB.

(b) Then following a 16-hour stand, the cells were individually discharged at the c/5 rate (2.0 amperes) to an end voltage of 1.3 volts. The cells were allowed to stand 1 to 5 hours before recharging.

(2) The third cycle consisted of:

(a) A charge at the c/20 rate (500 milliamperes) for 24 hours to give an input of 120 percent of the manufacturer's rated capacity. At the end of charge, the electrolyte level was adjusted to the tops of the plates using 20 percent KOH electrolyte supplied by ESB.

(b) Then following a 16-hour stand, the cells were individually discharged at the c/1 rate (10.0 amperes) to an end voltage of 1.3 volts.

(3) The fourth charge was at the c/20 rate (500 milliamperes) for 24 hours to give an input of 120 percent of the manufacturer's rated capacity. At the end of charge, the electrolyte level was adjusted to the top of the plates using 20 percent KOH electrolyte supplied by ESB.

d. Constant Potential Charge Test (5 cells of each separator type or combination used):

(1) The cells were allowed to stand on open circuit for 16 hours following the recharge in paragraph 11.c.(3).

(2) They were then discharged individually at the c/5 rate (2.0 amperes) to a terminal voltage of 1.3 volts and, then allowed to stand on open circuit from 1 to 5 hours before recharging.

(3) These cells were then charged at a constant potential of 1.99 + 0.01 volts per cell average for 24 hours with a maximum current of 500 milliamperes. Following the charge, the cells were allowed to stand for 2 hours during which time electrolyte (20 percent KOH) was added as necessary to maintain the electrolyte level at the top of the plates.

(4) These cells were cycled continuously as outlined in paragraphs 11.d.(2) and 11.d.(3) until each cell failed to deliver a minimum of 4.0 ampere-hours.

e. Constant Current Charge Test (5 cells of each separator type or combination used):

(1) The cells were allowed to stand on open circuit for 16 hours following the recharge in paragraph 11.c.(3).

(2) They were then discharged individually at the c/5 rate (2.0 amperes) to a terminal voltage of 1.3 volts, and then allowed to stand on open circuit from 1 to 5 hours before recharging.

(3) The cells were then charged at a constant current rate of c/20 (500 milliamperes) until 120 percent of the capacity each cell delivered on the previous discharge was returned. Following completion of charge of the last cell, the cells were allowed to stand in the charged condition for 2 hours, during which time electrolyte (20 percent KOH) was added as necessary to maintain the level at the top of the plates.

(4) These cells were cycled continuously as outlined in paragraphs 11.e.(2) and 11.e.(3) until each cell failed to deliver a minimum of 4.0 ampere-hours.

f. Charged-Stand Test (5 cells of each separator type or combination used):

(1) The cells were allowed to stand on open circuit for 16 hours following the recharge in paragraph 11.c.(3).

(2) These cells were then discharged individually at the c/5 rate (2.0 amperes) to a terminal voltage of 1.3 volts, and then allowed to stand on open circuit from 1 to 5 hours before recharging.

(3) The cells were then charged at a constant current rate of c/20 (500 milliamperes) until 120 percent of the capacity each cell delivered on the previous discharge was returned. Near the end of charge, electrolyte (20 percent KOH) was added as necessary to maintain the level at the top of the plates. The cells were allowed to stand in the charged condition for 30 days.

(4) These cells were cycled continuously as outlined in paragraphs 11.f.(2) and 11.f.(3) until each cell failed to deliver a minimum of 4.0 ampere-hours.

g. Recording of Test Results:

(1) Discharges: Following the open circuit cell voltage readings, the cell voltages and current were recorded at 1 minute, 15 minutes, 30 minutes, and every 30 minutes thereafter to the specified cutoff of 1.3 volts per cell.

(2) Recharges: Following the open circuit cell voltage readings, the cell voltages were recorded 1 minute after start of charging and hourly thereafter to completion of charge.

(3) 30-Day Stand: Following the recharge, the open circuit cell voltages were recorded daily.

h. The first cell in each 5-cell test group to fail was sent to: ESB, Inc., Carl F. Norberg Research Laboratory (Mr. Jack Kelly), Yardley, Pennsylvania 19067.

12. 5xESB100 (Bellows and Auxiliary Electrode):

a. Five experimental 100 ampere-hour, silver-cadmium cells were assembled by ESB, Inc.

b. The cell cases were made of polystrene, each fitted with a pressure gage and pressure venting valve. In the bottom of each cell was a bellows assembly to regulate the electrolyte level. In physical contact with the bellows assembly was a pressure activated switch which opens when the internal pressure exceeds 15 psig and terminates charging. Each cell is equipped with an auxiliary electrode for the recombination of oxygen during charging. The separator materials are of a design to permit rapid drainage of the negative plates during charge. The bellows and special separator material work together to maximize oxygen recombination by the auxiliary electrode during charge.

c. These cells were submitted for test and evaluation of the bellows system to control the electrolyte level; the pressure switch in the bellows to cutoff charge when the internal pressure exceeds 15 psig; and the recombination characteristics of the auxiliary electrode in these cells.

d. Test Procedure:

(1) Preparation and Capacity Tests: Each cell was restrained by two 1/4-inch aluminum plates that were placed against the sides with the greatest area. A 2.2-ohm resistor was connected between the auxiliary electrode and the negative terminal of each cell. The pressure sensitive switches in the cells were connected in series and attached to the alarm system. The cells were discharged individually through 1-ohm resistors until the voltage dropped below 0.5 volt. The cells then received two capacity discharge cycles, each consisting of a charge at 5.0 amperes; followed by a discharge at 10 amperes for the first capacity check and at 15 amperes for the second capacity test. During charge at 5.0 amperes, each cell was removed from the charge circuit when its on-charge voltage reached 1.55. The individual cell and auxiliary electrode voltages were monitored during these charging periods. The cells were discharged individually to 0.8 volt for both discharge rates. Prior to cycling, the cells were recharged at 5.0 amperes, removing each cell from the charging circuit when its on-charge voltage reached 1.55.

(2) Cycling:

(a) The discharge-charge cycling consists of 2-hour discharges at 15.0 amperes followed by 22-hour charge periods at 3.0 amperes. The discharge voltage limit is 0.8 volt per cell; and the on-charge voltage limit is 1.51 volts per cell average, or 7.55 volts for the 5-cell pack.

(b) The cell parameters recorded during cycling are the pack voltage, current, cell voltages, auxiliary electrode voltages and internal cell pressures. These parameters are recorded at the beginning and end of discharge. During every seventh cycle, these parameters are also recorded every 15 minutes during discharge and every hour during charge.

13. Douglas Separator Test, 4xDA5-1 Astropower Cells:

a. Four 5.0 ampere-hour, silver-zinc cells were assembled with Douglas inorganic separators. Each cell was equipped with a pressure relief valve.

b. The purpose of this test is to evaluate the performance of the Douglas inorganic separator material in silver-zinc cells.

c. Test Procedure:

(1) The cells were individually discharged through a 1-ohm resistor to 1.0 volt.

(2) They were charged at 350 milliamperes, and each removed from the charging circuit when its on-charge voltage reached 2.05 volts. Then the cells were discharged at 2.5 amperes to 1.0 volt.

(3) Two cells were charged at 350 milliamperes to an on-charge voltage of 2.05 volts each; and then discharged at 2.5 amperes to 1.0 volt while being vibrated to the OAO specification.

(4) Following the vibration test, all four cells were given two cycles of charge and discharge as stated in paragraph 13.c.(2). During the first cycle one of the cells that had been vibrated showed a drastic loss of capacity. This cell was returned to Goddard Space Flight Center for analysis. The analysis showed that all but two wires (one positive and one negative) connecting the plates to the terminals had broken.

(5) The three remaining cells were then charged at 350 milliamperes to 2.05 volts each, and placed in a temperature chamber at 0° C for 24 hours prior to the following sequence.

(a) The cells were discharged at 2.5 amperes to 1.0 volt. Next, they were recharged at 350 milliamperes to 2.05 volts each, and again discharged at 2.5 amperes to 1.0 volt each.

(b) The temperature was then raised to 25° C and the discharge resumed at 2.5 amperes to 1.0 volt each to remove the residual capacity.

(6) Cycling: The cells are now being cycled to failure by:

(a) Charge at 350 milliamperes to 2.05 volts.

(b) Allow cells to stand on 30-day open circuit stand.

(c) Discharge at 2.5 amperes to 1.0 volt each.

(7) Monitoring: The current and cell voltages are being recorded every 30 minutes during charge, and every 10 minutes during discharge. The cell voltages during the 30-day open circuit stand are being recorded daily.

14. Yardney Plate and Separator Test:

a. Twelve 12 ampere-hour, silver-zinc cells were assembled by Yardney Electric Corporation, with two different negative plate materials, and two different separator materials. Each cell was equipped with a pressure gage. Testing was halted temporarily when pressures exceeded the maximum specified limit of 10 psig during charge to confer with Goddard Space Flight Center for test modifications. The two types of cells are as follows:

(1) Type 2: Nine cells K969, serial numbers 18 through 26. The negative plates contained 5.0 percent teflon. The separator consisted of five layers of C-19.

(2) Type 3: Three cells K969, serial numbers 30, 37 and 38. The negative plates contained 0.5 percent CMC. The separator consisted of five layers of RAI 2.2XH.

b. These two cell types were submitted for test and evaluation of the negative plates with their respective additives, each type with a 5-layer wrap of different separator material. Cells of only two of the four proposed types have been submitted to date.

c. Initial Tests:

(1) The cells were charged in series at 1.0 ampere, and each removed from the charging circuit when it reached an on-charge voltage of 2.00 volts.

(2) Following an open circuit stand of 1 hour after charge of the last cell was completed, the cells were discharged at 3.0 amperes. Each cell was removed from the discharge circuit when its voltage reached 1.30.

(3) Following a 2-hour open circuit stand, the charge and discharge of paragraphs 14.c.(1) and 14.c.(2) were repeated.

d. Cycling Test:

(1) The cells were charged in series at 1.0 ampere to a voltage limit of 1.97 volts per cell for 30 hours. The voltage of any one cell was not to exceed 1.97 volts nor the pressure to exceed 10 psi. Following completion of charge, the cells were allowed to stand open circuit for 2 hours before being discharged.

(2) The cells were discharged individually at 3.0 amperes to 1.30 volts. Following completion of discharge, the cells were allowed to stand open circuit for 1 to 5 hours before being placed on charge.

(3) At the beginning of cycling, all 12 cells were connected in series. The voltage limit could not be controlled on each cell by this means. When any cell would reach the 1.97 voltage limit, the voltage

limit of the power supply was manually reset to maintain the voltage at 1.97 volts. This resulted in a voltage decrease in the cells with lower voltage and a pressure increase in the cells with higher voltage.

(4) The cells were then divided into two groups of six cells; each with a power supply. The situation described above was still observed and the cells required constant monitoring.

e. Changes in the test procedure:

(1) To keep the cells from damaging themselves, the test procedure was altered as follows:

(a) The cells were charged at 1 ampere until the first cell reached 1.97 volts, then the charging current was reduced to 100 milliamperes.

f. Monitoring:

(1) The cell voltages were recorded hourly on charge and every 15 minutes on discharge.

15. General Performance Tests:

a. The purpose of this program is to gather specific information concerning sealed nickel-cadmium cells designed for use in spacecraft.

b. Environmental Characteristics:

(1) Each cell not equipped with a pressure gage shall receive the following environmental tests:

(a) Random Vibration: The cells shall be vibrated for 8 minutes in each of the three axes at the frequencies and levels shown below.

Longitudinal Axis		Lateral Axes	
Frequency	Level	Frequency	Level
15 - 70	$0.030g^2$/cps	15 - 70	$0.030g^2$/cps
70 - 400	$0.0225g^2$/cps	70 - 150	$0.0225g^2$/cps
400 - 800	$0.045g^2$/cps	150 - 2000	$0.030g^2$/cps
800 - 2000	$0.030g^2$/cps		

(b) Sinusoidal Vibration: The cells shall be subjected to sinusoidal vibration at a sweep rate of one octave per minute with two exposures per each axis at the frequencies and levels shown below.

Frequency	Level
5 - 8 cps	0.5" D.A.
9 - 14 cps	Linear decrease to 0.2" D.A.
15 - 54 cps	0.2" D.A.
55 - 2000 cps	30 g's

(c) Shock: The cells shall be subjected to two half-sine wave shock pulses of 30 ± 10 percent amplitude in each of the three mutually perpendicular axes.

(1) The time duration of the two pulses shall be 6 and 12 milliseconds ± 10 percent.

(d) Acceleration: The cells shall be subjected to acceleration at the g level and time for each axis specified below.

g Level	Axis	Duration
11.3	+X	4.5 Minutes/Axis
2.3	+Y, -Y	4.5 Minutes/Axis
2.3	+Z, -Z	4.5 Minutes/Axis
3.0	-X	4.5 Minutes/Axis

(2) During each phase of the random vibration, shock and acceleration tests, the cells shall be discharged at the c/2 rate. During each phase of the sinusoidal vibration test, the cells shall be discharged at the c/5 rate because of greater length of time required for the tests.

(3) Prior to each test, the cells shall be recharged at the c/10 rate for 16 hours.

c. Charge and Discharge Voltage Characteristics (All Cells):

(1) At various charge rates:

(a) While at room temperature, each cell shall be discharged to 0.0 volt at the c/2 rate and shorted out for a period of 30 to 60 minutes. The cells shall then be recharged at the c/10 rate for 16 hours. After a 15-minute open circuit stand, each cell shall be given a capacity discharge at the c/2 rate to 0.0 volt and then shorted out for a period of 30 to 60 minutes.

(b) A thermocouple shall be attached to the side of each of the five cells. The cells shall then be placed in a temperature chamber and allowed to stabilize at -20° C.

(c) The cells shall then be recharged at the c/40 rate (no voltage limit) to 100 percent of the manufacturer's rated capacity.

(d) After a 15-minute stand, each cell shall be discharged at the c/2 rate to 0.0 volt and shorted out for a period of 30 to 60 minutes.

(e) Paragraphs 15.c.(1)(c) and 15.c.(1)(d) shall be repeated for c/20, c/10, c/5, c/2, c/1 and 2c charge rates.

(f) Upon completion of above sequence with the seven charge rates, the tests of paragraphs 15.c.(1)(c), 15.c.(1)(d) and 15.c.(1)(e) shall be repeated at 0° C, 20° C and 40° C.

(g) On cells having auxiliary electrodes, the auxiliary electrode voltage shall be monitored across 47 ohms during both charge and discharge portions of the test.

(h) The results shall be shown graphically with cell charge and discharge voltages versus charge and discharge ampere-hours.

(i) At room temperature, the cells shall then be recharged at the c/10 rate for 16 hours. After a 15-minute stand, each cell shall be given a capacity discharge at the c/2 rate to 0.0 volts and shorted out for a period of 30 to 60 minutes.

(2) At Various Discharge Rates:

(a) The cells shall then be allowed to stabilize at -20° C.

(b) Using the charge rate from paragraph 13.c.(1)(e) above that resulted in the maximum ampere-hour efficiency, the cells shall be recharged (no voltage limit) to 100 percent of the manufacturer's rated capacity.

(c) After a 15-minute stand, each cell shall be discharged at the c/40 rate to 0.0 volt and shorted for a period of 30 to 60 minutes.

(d) Paragraphs 15.c.(2)(b) and 15.c.(2)(c) shall be repeated for c/20, c/10, c/5, c/2, c/1 and 2c discharge rates.

(e) Upon completion of the above sequence with the seven discharge rates, the tests shall be repeated at 0° C, 20° C and 40° C.

(f) On cells having auxiliary electrodes, the auxiliary electrode voltage shall be monitored across 47 ohms during both charge and discharge portions of the test.

(g) The results shall be shown graphically with cell discharge voltages versus discharge ampere-hours.

d. Overcharge Characteristics (All Cells):

(1) At the completion of the charge and discharge voltage characteristics sequence, the discharged cells shall be allowed to stabilize at room temperature. The cells shall then be recharged at the c/10 rate for 16 hours. After a 15-minute stand, each cell shall be given a capacity discharge at the c/2 rate to 0.0 volt and shorted out for 30 to 60 minutes.

(2) One cell shall then be placed and allowed to stabilize in an ambient of each of the four test temperatures: -20° C, 0° C, 20° C and 40° C. The fifth cell shall be kept as a spare in the event of catastrophic failure of any of the test cells.

(3) The four cells at their respective temperatures shall then be subjected to the overcharge sequence listed below:

(a) Charge at c/10 for 16 hours; wait 1 hour.

(b) Charge at c/40 until the cell voltage stabilizes.

(c) Charge at c/20 until the cell voltage stabilizes.

(d) Charge at c/10 until the cell voltage stabilizes.

(e) Charge at c/5 until the cell voltage stabilizes.

(f) Charge at c/2 until the cell voltage stabilizes.

(g) Charge at c/1 until the cell voltage stabilizes.

(h) Charge at 2c until the cell voltage stabilizes.

(4) All charging is at constant current with no voltage limit.

(5) A drop in voltage of 0.05 volt or more from the highest value observed, or temperatures above 77° C shall terminate the tests at that ambient temperature.

(6) On cells having auxiliary electrodes, the auxiliary electrode voltage shall be monitored across 47 ohms during both the charge and discharge portions of the test.

(7) The results shall be shown graphically as a plot of the cell voltage versus the log of the charging current.

e. Changes in Test Procedure:

(1) Due to severe gassing when charging the cells at the high rates at -20° C, NASA requested that the test temperature sequence of paragraphs 15.c.(1) and 15.c.(2) be changed to start with 40° C and then be lowered to 20° C, and 0° C and -20° C.

16. Operation of Silver-Cadmium Batteries in Parallel:

a. The purpose of this test is to obtain information on the characteristics of silver-cadmium batteries operating in parallel. Ten Yardney 12.0 ampere-hour cells, with oxygen fuel cell type auxiliary electrode material used for gas recombination, were subjected to the following tests:

b. Initial Conditioning:

(1) Each cell was discharged through a 1-ohm resistor for 16 hours.

(2) A 1-ohm resistor was connected between the auxiliary electrode and the negative terminal throughout all testing.

(3) The cells were charged at 900 milliamperes until each reached a terminal voltage of 1.55.

(4) The cells were then discharged individually at 4.0 amperes to 0.8 volt.

(5) Repeat the charge-discharge cycle of paragraphs 16.b.(3) and 16.b.(4) for a total of three cycles.

c. Cycling Procedure:

(1) The 10 cells were assembled into two 5-cell packs. Each pack consists of cells more nearly matched in ampere-hour capacity.

(2) The packs were charged individually at the c/10 rate (1.2 amperes) for 24 hours.

(3) The packs were then connected in parallel and cycled as follows:

(a) Discharge: The discharge rate for the two packs in parallel was 6.0 amperes for 1 hour.

(b) Charge: The maximum charge rate for the two packs in parallel was 2.4 amperes for 9 hours with a voltage limit of 7.50 volts (1.50 volts per cell, average).

(4) Recording of Test Results:

(a) For Each Cycle: The total voltage, current, individual cell voltages, and the auxiliary electrode voltages were recorded at the beginning and the end of the discharge and the charge periods.

(b) Once each week the total voltage, current, individual cell voltages, and the auxiliary electrode voltages were recorded every 10 minutes during discharge and every 30 minutes during charge.

(c) Charging Efficiency: The ampere-hours delivered and the ampere-hours accepted on the succeeding recharge by each pack were recorded for each cycle for determination of charging efficiency.

17. Synchronous Orbit (General Electric 12.0 ah):

a. Thirty General Electric, 12.0 ampere-hour (17 with auxiliary electrodes) sealed, nickel-cadmium cells are being tested under conditions simulating those aboard a synchronous orbit satellite. The purpose of the test is evaluation of auxiliary electrode for charge control in synchronous type orbit.

b. The pressure gages of six cells were replaced by pressure transducers.

c. The 30 cells are assembled into six 5-cell packs; each containing a cell with a pressure transducer inserted in the pressure gage fitting; and cells with and without auxiliary electrodes.

d. Test parameters:

(1) Packs 7 and 8 are cycling at 0° C ambient, at 60 and 80 percent depth of discharge respectively.

(2) Packs 9 and 10 are cycling at 20° C ambient, at 60 and 80 percent depth of discharge respectively.

(3) Pack 11 is cycling at 40° C ambient, at 60 percent depth of discharge.

(4) Pack 12 is cycling at -20° C ambient, at 80 percent depth of discharge.

e. A thermocouple is located on the face of the center cell of each pack.

f. Initial Cycle:

(1) Each pack was charged at the c/10 rate (1.2 amperes) for 16 hours, followed by a discharge at the c/2 rate (6.0 amperes) to 0.5 volt for any individual cell. The packs were then recharged at the c/4 rate (3.0 amperes) to the auxiliary electrode trip voltage (300 mv), followed by a discharge at the c/2 rate to 0.5 volt for any cell. The third cycle consisted of a charge at the c/4 rate (3.0 amperes) to the auxiliary electrode trip voltage (300 mv), followed by a discharge at a rate determined by the maximum depth of discharge on the longest shadow period (72 minutes) to 0.5 volt for any cell. The pack was then charged at the c/4 rate (3.0 amperes) to the auxiliary electrode trip voltage (300 mv) followed by the cycling regime.

(2) The duration of the discharge of the first day of each 42-day shadow period was 0.2 hour. The discharge time for the succeeding days through the 17th day was increased by uniform increments to 1.2 hours and held at 1.2 hours for each of the succeeding 3 days. On the 21st day,

the packs were discharged at the cycle rate to 0.5 volt for any cell. The discharge time for the four succeeding days through the 25th day was 1.2 hours. Then during the last 17 days of each 42-day shadow period, the daily discharges were decreased by uniform increments to 0.2 hour. The current for the various daily discharge periods for each pack throughout the 42-day shadow period was a constant current value as follows:

(a) 6 amperes for packs cycling at 60 percent depth of discharge.

(b) 8 amperes for packs cycling at 80 percent depth of discharge.

(3) Charging for all packs was by constant current at 3.0 amperes to the auxiliary electrode trip voltage of 300 mv at which time the charging rate was reduced to 200 ma.

g. Adjustments During Cycling:

(1) During the 12th cycle, pack 7 at 0° C and 60 percent depth of discharge, the charge rate was reduced from 3.0 to 1.5 amperes whereas that for pack 8 at 0° C and 80 percent depth of discharge was left at 3.0 amperes. The auxiliary electrode trip voltage of both packs was reduced from 300 mv to 150 mv.

(2) During the 17th cycle, pack 11 at 40° C and 60 percent depth of discharge, the auxiliary electrode trip voltage was increased from 300 to 500 mv and the trickle charge rate was increased from 200 to 600 ma.

(3) During the 4th cycle recharge, pack 12 at -20° C was allowed to continue trickle charge at 20 ma for a total of 43.6 hours to lower the internal pressure by recombination of the gases. This was followed by an open circuit period of 75 hours. The reduction in internal pressure as evidenced by a drop from 209 to 200 mv is insignificant (320 mv = 100 psig). Following the discharge on the 9th day (5th cycle) the charge current was reduced from 3.0 amperes to 400 ma, the auxiliary electrode trip voltage from 300 to 150 mv, and the trickle charge current from 200 ma to 40 ma. On the 10th day the charge voltage control of the pack was changed from cells 4 and 5 to cells 3 and 5.

(4) On the 16th day, the auxiliary electrode of pack 12 at -20° C did not rise to the 150 mv trip voltage thus allowing the charge to continue at 400 ma for the balance of the charging period for each of the cycles through cycle 22. On discharge the cell voltages were down to 0.5 volt. On the 23rd day the charging current was increased from 400 ma to 600 ma and the trickle charge current was increased from 40 ma to 120 ma. The auxiliary electrode tripped at 150 mv allowing charge to trickle at 120 ma.

(5) From the 27th to 42nd day the charge current for pack 12 at -20° C remained at 600 ma. The trickle charge current we reduced to 40 ma. The trickle current remained at 40 ma. When the cell voltages or pack voltage were too high the trickle current was reduced manually.

h. After shadow period, the packs are on charge at trickle rate for 140 days prior to next shadow period. The trickle charge rate was 200 ma for packs 7, 8, 9 and 10; 600 ma for pack 11 and 0 ma for pack 12.

18. Synchronous Orbit (General Electric 6.0 ah):

a. Thirty G.E., 6.0 ampere-hour, sealed, nickel-cadmium cells are being tested under conditions similar to those aboard a synchronous orbit satellite. The purpose of the test is to establish the life capabilities of nickel-cadmium space cells for communications satellites and similar missions in synchronous orbits.

b. Acceptance Test:

(1) Capacity Test: Subject the cells to a series of three capacity checks as follows:

(a) Charge the cells for 16 hours at the c/10 rate (600 milliamperes).

(b) Allow cells to stand for 1 hour before discharging.

(c) Discharge the cells individually at the c/2 rate (3.0) amperes) to a cutoff of 1.00 volt per cell.

(d) Record cell voltages every 10 minutes on discharge and every hour on charge.

(2) Cell Short Test: Following completion of the third capacity check discharge:

(a) Load each cell with a resistor of a value giving a c/1 to c/5 (6.0 amperes to 1.2 amperes) discharge rate.

(b) Allow the cells to stand for 16 hours with the resistors acting as a shorting device.

(c) Remove resistors and allow cells to stand on open circuit for 24 hours.

(d) Record cell voltages hourly.

(3) Immersion Seal Test:

(a) Place the cells under water in a bell jar.

(b) Reduce the pressure in the bell jar to 10 inches of mercury and hold for 3 minutes.

(c) During this 3-minute period scrutinize the cells for a steady stream of bubbles, thereby indicating a leak around a seal or weld.

(4) Overcharge Test:

(a) Charge the cells at each of three rates for 48 hours as follows:

1. c/20 (300 milliamperes).

2. c/10 (600 milliamperes).

3. c/5 (1.2 amperes).

(b) Record the cell voltages hourly.

(c) Discontinue charging of any cell that exceeds 1.50 volts.

(5) Internal Resistance Test:

(a) At the completion of the overcharge test return the cells to the c/20 (300 milliamperes) charging rate, $I_{c/20}$.

(b) While charging at this rate, pulse the charging current at the c rate (6.0 amperes), I_c, for 5 to 10 seconds.

(c) Record the cell voltage, V_1, immediately prior to the pulse, and the cell voltage, V_2, 5 milliseconds after initiation of the pulse.

(d) Calculate the internal resistances of the cells according to:

$$R = \frac{V_2 - V_1}{I_c - I_{c/20}}$$

(6) Repeat the immersion seal test.

c. Test Parameters:

(1) The cells were grouped into six 5-cell packs, two of which were equipped with a coulometer for charge control.

(2) The packs are being tested under the conditions listed below:

Pack Number	Test Temperature	Depth of Discharge	Recharge Current (amps)	Trickle Current (amps)
Sync 4	-20° C	40%	0.200	0.200
Sync 3	0° C	40%	0.200	0.200
Sync 5	0° C	60%	0.300	0.200*
Sync 6	0° C	80%	0.400	0.200*
Sync 2	25° C	40%	0.200	0.200
Sync 1	40° C	40%	0.200	0.200

* Coulometer Controlled.

d. Initial Cycle:

(1) Each pack was charged at the c/10 rate (600 milliamperes) for 16 hours, followed by a discharge for 1 hour at the respective cycle rate (2.0, 3.0 or 4.0 amperes) as noted in paragraph 18.e.(2). The packs were then returned to continuous charge for 60 days at the respective rate noted in paragraph 18.c.(2).

e. Cycling Procedure:

(1) During the periods from the 61st through the 100th day and from the 241st through the 280th day of orbiting, these packs were subjected to 24-hour discharge-charge cycling to simulate the so called 40-day shadow periods experienced by the battery aboard a synchronous orbit satellite.

(2) The duration of the discharge of the first day of each 40-day shadow period was 0.2 hour. The discharge time for the succeeding days up through the 16th day was increased by uniform increments to 1.2 hours and held at 1.2 hours for each of the succeeding 8 days. Then during the last 16 days of each 40-day shadow period, the daily discharges were decreased by uniform increments to 0.2 hour. The current for the various daily discharge periods, for each pack throughout the 40-day shadow period was of a uniform value as follows:

(a) 2.0 amperes for packs Sync 1 through 4.

(b) 3.0 amperes for pack Sync 5.

(c) 4.0 amperes for pack Sync 6.

(3) Charging was by constant current at the specified rate, with the proper trickle rate on packs Sync 5 and Sync 6, which are equipped with Gulton 6.0 ah coulometers.

(4) While cycling during the shadow periods, the individual cell voltages, and the total voltage and current were measured with a digital voltmeter and recorded. Readings were recorded five times during discharge; 1 minute after start and 1 minute before the end of discharge with three readings in between at equally spaced time intervals. When the time interval between the intermediary readings reached 10 minutes, additional readings were taken as necessary to prevent the equally spaced readings from exceeding 10 minutes. During charge periods, the readings were taken hourly.

(5) Between the shadow periods, the individual cell voltages, total voltage and current were measured with a digital voltmeter at 0200, 1000 and 1800 hours daily and recorded.

19. Three 5.0 Ampere-Hour, Zinc-Oxygen Cells, manufactured by Union Carbide:

a. Purpose:

(1) The purpose of this test is to ascertain the applicability of the zinc-oxygen cells to the space program and to determine:

(a) Their capability of delivering reliable power over an appreciable span of time.

(b) What can be done to "squeeze" more life out of the cells.

(c) Whether a continuous flow of oxygen to the cell when under load is necessary, or whether the flow could be "dead-ended" to minimize the consumption of oxygen.

(d) The type of "plumbing" necessary.

(e) The number of watt-hours per pound that may be expected under various methods of calculation.

(f) Any additional information as revealed by the data.

b. Cell Description:

(1) The cells are encased in transparent plastic, and have three electrodes: a carbon catalyzed, oxygen fuel cell electrode; a nickel charging electrode; and a zinc electrode which serves as a common negative during both the charge and discharge modes of operation. The nickel charging electrode is used to avoid oxidation and consequent degradation of the oxygen electrode.

(2) The 5.0 ampere-hour cells are rectangular in shape and are supported on a plexiglass pedestal.

(3) The present type of cells are equipped with miniature three-way stopcocks for venting and adjustment of electrolyte levels. Thus far this has proved to be superior to the self-sealing plugs through which syringes were inserted for electrolyte injection or withdrawal.

c. Test Conditions:

(1) The cells are received in a dry condition. Thus to precondition the cells, add electrolyte and allow to stand 48 hours to insure complete wetting before start of cycling. The anolyte consists of 41 percent KOH plus 7 percent ZnO, and the catholyte consists of 41 percent KOH.

(2) Testing shall be performed at existing relative humidity, atmospheric pressure and room temperature. The tests consist of:

(a) Cycling on a 2-hour charge, 2-hour discharge regime.

(b) Gas sampling at the end of charge and end of discharge by means of a gas chromatograph.

(3) All charging and discharging shall be done at constant current (0.700 ampere discharge and 0.721 ampere charge). The power supply shall be programmed to deliver a 103 percent recharge.

20. One hundred, 12 ampere-hour, Silver-Cadmium Cells, manufactured by Gulton:

a. Purpose:

(1) Evaluation of cells by acceptance tests prior to life cycling.

b. Acceptance tests shall be performed at room temperature (22° to 29° C).

c. Cell Preparation:

(1) Record weights and measurements of all cells.

(2) Place cells in groups of 10 by ascending order of serial numbers.

(3) Visually inspect cells and note any defects.

d. Mechanical Leakage Test:

(1) Thoroughly wash all cells with distilled water until no evidence of discoloration of pink litmus paper (to blue) by the wash water.

(2) Test areas of closure by both of the following methods:

(a) Wipe closure areas with wet pink litmus paper and note discoloration (to blue).

(b) Wet closure areas with phenolphthalein solution (colorless) and note coloration if any (to shades of pink).

1. Exercise care in the use of litmus paper or the phenolphthalein solution so that the terminals are not shorted.

(3) Visually inspect cells for evidence of cracks or blisters and note observations.

e. Capacity Discharge Test:

(1) Charge the cells at the c/16 rate (750 milliamperes) to 1.60 volts per cell average. Record the total time on charge.

(2) Place the cells on open circuit stand for 24 hours.

(3) Discharge the cells at the c/4 rate (3 amperes).

(a) Remove each cell, in turn, from the discharge when it reaches the cutoff of 1.0 volt. Record discharge time of each cell to 1.0 volt.

(4) Repeat the charge-discharge cycle, paragraphs 20.e.(1) through 20.e.(3)(a) for a total of three cycles.

1. The cells are expected to deliver a minimum of 12.0 ampere-hours on the third discharge even though they may do so on the first and/or second discharges.

f. Cell Short Test:

(1) Following the third discharge of paragraph 20.e. to 1.0 volt cutoff for the individual cells:

(a) Place a 0.2 ohm resistor across each cell for 16 hours.

(b) Remove resistors and place cells on open circuit stand for 1 week.

(c) Record individual cell voltages at the end of each 24-hour period.

1. At the end of 1 week of open circuit stand, the individual cell voltages must be greater than 1.10 volts.

g. Mechanical Leakage Test:

(1) Repeat steps in paragraph 20.d.

h. Overcharge Test:

(1) Charge the cells at the c/16 rate (750 milliamperes) to 1.55 volts per cell, average. Record the time on charge.

(2) Lower the on-charge voltage to 1.51 volts per cell, average.

(3) Continue charging at 1.51 volts per cell, average, for 1 week. Record hourly the current and the cell voltages.

(4) During the last 10 minutes of the 1-week charge, measure and record the cell length (for use in determining expansion of the cell).

1. It is expected that the expansion of the individual cell will be less than that caused by a pressure of 30 pounds per square inch absolute (30 psia). A table will be supplied.

(5) Following measurement of individual cell lengths:

(a) Discharge the cells at the c/4 rate (3.0 amperes) to 1.0 volt per cell, average.

(b) Record current and individual cell voltages every 15 minutes.

(6) During the c/4 discharge of paragraph 20.h.(5) apply 60-millisecond pulse discharges of 15.0 amperes at the following times:

(a) One minute after the start of the c/4 discharge and hourly thereafter. Record pulse voltages of the individual cells on a high speed recorder.

1. The voltage of each cell must remain greater than 0.9 volt during the 15.0 ampere pulses as recorded on a high speed recorder.

i. Mechanical Leakage Test:

(1) Repeat steps in paragraph 20.d.

TEST RESULTS AS OF 31 OCTOBER 1969

1. Burgess-Borden Separator Test (Paragraph 1, Enclosure (1)):

a. Charged Stand Test:

(1) Pack 16 (5 cells with C-3 separators and 5 with 9107/12 separators):

(a) Date Started: 17 February 1966

(b) Initial Number of Cells: 10

(c) Cells Remaining on Test: 0

(d) Cycles to Failure: 27

(e) Removed from Test: 11 July 1968

(2) Pack 17 (5 cells with C-3 separators and 5 with 9107/12 separators):

(a) Date Started: 17 February 1966

(b) Initial Number of Cells: 10

(c) Cells Remaining on Test: 0

(d) Cycles to Failure: 39

(e) Removed from Test: 20 July 1969

2. Open Circuit and Overcharge Test; Sonotone 3.5 Ampere-Hour Nickel-Cadmium Cells (Paragraph 2, Enclosure (1)):

a. Open Circuit Stand Test:

(1) Date Started: 14 March 1966

(2) Initial Number of Cells: 10

(3) Cells Remaining on Test: 7

(4) Cells are on fourth open circuit stand test.

b. Overcharge Test:

(1) Date Started: 14 March 1966

(2) Initial Number of Cells: 10

(3) Cells Remaining on Test: 7

(4) Cells are on fourth overcharge test.

c. The acceptance test following a 1-year stand was conducted during April 1967. The acceptance test following the second year stand was conducted during June 1968. The acceptance test following the third year stand was conducted during July 1969.

3. IMP E #10; Yardney, 10 Ampere-Hour, Silver-Cadmium Battery (Paragraph 3, Enclosure (1)):

a. Date Started: 29 July 1966

b. Initial Number of Cells: 13

c. Cells Remaining on Test: 13

d. Cycles to Date: 1648

4. IMP F, #4; Yardney, 3.0 Ampere-Hour, Silver-Cadmium Battery (Paragraph 4, Enclosure (1)):

a. Date Started: 24 August 1967

b. Initial Number of Cells: 13

c. Cells Remaining on Test: 0

d. Cycles to Failure: 24 and 603 days of Float Charge

e. Removed from Test: 1 October 1969

5. Synchronous Orbit 10HR16(S)-1 #4; Yardney, 16 Ampere-Hour, Silver-Zinc Cells (Paragraph 5, Enclosure (1)):

a. Date Started: 6 December 1966

b. Initial Number of Cells: 10

c. Cells Remaining on Test: 0

d. Cycles to Removal: 585 days to 31 May 1969

e. Pack removed from test and forwarded to Goddard Space Flight Center.

6. Yardney Separator and Plate Test (Paragraph 6, Enclosure (1)):

a. Pack 1 (5 K969 cells with RAI 2.2XH, series 2, separators):

(1) Date Started: 14 September 1967

(2) Initial Number of Cells: 5

(3) Cells Remaining on Test: 0

(4) Cycles to Failure: 153

(5) Removed from Test: 18 July 1968

b. Pack 2 (5 K969 cells with teflon negatives and emulphogene):

(1) Date Started: 30 August 1967

(2) Initial Number of Cells: 5

(3) Cells Remaining on Test: 0

(4) Cycles to Failure: 318

(5) Removed from Test: 18 June 1969

c. Pack 3 (5 K1100 cells with negative edges extended):

(1) Date Started: 30 August 1967

(2) Initial Number of Cells: 5

(3) Cells Remaining on Test: 1

(4) Cycles to Date: 387

7. Polymerized Neoprene Seal Overcharge Test, Gulton, 3.5 Ampere-Hour, Nickel-Cadmium Cells (Paragraph 7, Enclosure (1)):

a. Date Started: 5 December 1966

b. Initial Number of Cells: 5

c. Cells Remaining on Test: 4

d. Days of Continuous Overcharge: 1001

e. Cell No. 1--3.41 volts put on open circuit 31 August 1969.

8. S cubed, 6902-6YS3TB; Yardney, 3.0 Ampere-Hour, Silver-Cadmium Batteries (Paragraph 8, Enclosure (1)):

a. Date Started: 18 June 1969

b. Initial Number of Cells: 15

c. Cells Remaining on Test: 15

d. Cycles to Date:

(1) Pack No. 1: 335

(2) Pack No. 2: 386

(3) Pack No. 3: 399

9. S cubed, 5XYS5(S) C-34; Yardney, 3.0 Ampere-Hour, Silver-Cadmium Batteries (Paragraph 9, Enclosure (1)):

a. Date Started: 3 October 1967

b. Initial Number of Cells: 10

c. Cells Remaining on Test: 0

d. Cycles to Removal: 476

(1) Both batteries were put on continuous charge 3 March 1968. Test discontinued.

10. ESB-Borden Separator Evaluation Test (Paragraph 10, Enclosure (1)):

a. Constant Potential Charge Test:

(1) Pack 1 (5 cells with 9107-27 and 5 with 9107-29 separators):

(a) Date Started: 9 October 1967

(b) Initial Number of Cells: 10

(c) Cells Remaining on Test: 0

(d) Cycles to Failure: 106

(e) Removed from Test: 17 May 1968

(2) Pack 4 (5 cells with 9107-27/29 and 5 with 9107-C3 separators):

(a) Date Started: 24 October 1967

(b) Initial Number of Cells: 10

(c) Cells Remaining on Test: 0

(d) Cycles to Failure: 113

(e) Removed from Test: 16 June 1968

b. Constant Current Charge Test:

(1) Pack 2 (5 cells with 9107-27 and 5 with 9107-29 separators):

(a) Date Started: 9 October 1967

(b) Initial Number of Cells: 10

(c) Cells Remaining on Test: 0

(d) Cycles to Failure: 318

(e) Removed from Test: 23 March 1969

(2) Pack 5 (5 cells with 9107-27/29 and 5 with 9107-C3 separators):

(a) Date Started: 2 November 1967

(b) Initial Number of Cells: 10

(c) Cells Remaining on Test: 0

(d) Cycles to Failure: 230

(e) Removed from Test: 1 January 1969

c. Charged Stand Test:

(1) Pack 3 (5 cells with 9107-27 and 5 with 9107-29 separators):

(a) Date Started: 18 October 1967

(b) Initial Number of Cells: 10

(c) Cells Remaining on Test: 5

(d) Cycles to Date: 24

(2) Pack 6 (5 cells with 9107-27/29 and 5 with 9107-C3 separators):

(a) Date Started: 24 October 1967

(b) Initial Number of Cells: 10

(c) Cells Remaining on Test: 4

(d) Cycles to Date: 23

11. ESB-Borden Separator Evaluation Test (Paragraph 11, Enclosure (1)):

a. Constant Potential Charge Test:

(1) Pack 8 (5 cells with SK9211-1 separators):

(a) Date Started: 20 May 1969

(b) Initial Number of Cells: 5

(c) Cells Remaining on Test: 5

(d) Cycles to Date: 32

(2) Pack 12 (5 cells with SK9211-2 separators):

(a) Date Started: 20 May 1969

(b) Initial Number of Cells: 5

(c) Cells Remaining on Test: 0

(d) Cycles to Failure: 79

(e) Removed from Test: 29 October 1969

(3) Pack 9 (5 cells with SK9211-3 separators):

(a) Date Started: 30 May 1969

(b) Initial Number of Cells: 5

(c) Cells Remaining on Test: 0

(d) Cycles to Failure: 79

(e) Removed from Test: 29 October 1969

(4) Pack 15 (5 cells with SK9211-1 separators):

(a) Date Started: 2 September 1969

(b) Initial Number of Cells: 5

(c) Cells Remaining on Test: 5

(d) Cycles to Date: 36

b. Constant Current Charge Test:

(1) Pack 10 (5 cells with SK9211-1 separators):

(a) Date Started: 26 June 1969

(b) Initial Number of Cells: 5

(c) Cells Remaining on Test: 5

(d) Cycles to Date: 45

(2) Pack 11 (5 cells with SK9211-3 separators):

(a) Date Started: 26 June 1969

(b) Initial Number of Cells: 5

(c) Cells Remaining on Test: 4

(d) Cycles to Date: 56

(3) Pack 13 (5 cells with SK9211-2 separators):

(a) Date Started: 26 June 1969

(b) Initial Number of Cells: 5

(c) Cells Remaining on Test: 0

(d) Cycles to Failure: 50

(e) Removed from Test: 28 October 1969

(4) Pack 16 (5 cells with SK9211-1 separators):

(a) Date Started: 2 September 1969

(b) Initial Number of Cells: 5

(c) Cells Remaining on Test: 5

(d) Cycles to Date: 27

c. Charged Stand Test:

(1) Pack 7 (5 cells with SK9211-3 separators):

(a) Date Started: 20 May 1969

(b) Initial Number of Cells: 5

(c) Cells Remaining on Test: 5

(d) Cycles to Date: 5

(2) Pack 6 (5 cells with SK9211-1 and 5 with SK9211-2 separators):

(a) This pack of 10 cells was inadvertantly shorted externally by the operator, resulting in noticeable damage to one of the 5-cell groups. Although the cells of the remaining 5-cell group showed no visual damage, testing was discontinued on these 10 cells to prevent the use of data which may make meaningless the evaluation of the separators of this test.

(3) Pack 14 (5 cells with SK9211-1 separators):

(a) Date Started: 2 September 1969

(b) Initial Number of Cells: 5

(c) Cells Remaining on Test: 5

(d) Cycles to Date: 5

12. 5xESB100; ESB 100 Ampere-Hour, Silver-Cadmium Cells equipped with Bellows and Auxiliary Electrode (Paragraph 12, Enclosure (1)):

a. Date Started: 31 March 1967

b. Initial Number of Cells: 5

c. Cells Remaining on Test: 0

d. Cycles to Failure: 840

e. Removed from Test: 22 July 1969

13. Douglas Inorganic Separator Test; 4xDA5-1 Astropower Cells (Paragraph 13, Enclosure (1)):

a. Date Started: 24 August 1967

b. Initial Number of Cells: 4

c. Cells Remaining on Test: 0

d. Cycles to Failure: 10 30-day Stands

e. Removed from Test: 24 July 1968

14. Yardney Plate and Separator Test (Paragraph 14, Enclosure (1)):

a. Date Started: 7 December 1966

b. Initial Number of Cells: 12

c. Cells Remaining on Test: 0

d. Cycles to Failure: 196

e. Removed from Test: 6 January 1968

15. General Performance Tests (Paragraph 15, Enclosure (1)):

a. Five Gulton, 20 ah, Auxiliary Electrode, Nickel-Cadmium Cells:

(1) Date Started: 6 July 1967

(2) Test Completed: 6 February 1968

b. Five Gulton, 1.25 ah, Nickel-Cadmium Cells:

(1) Date Started: 14 April 1968

(2) Testing being held pending instructions from NASA, Goddard.

c. Five NIFE, 3.9 ah, Nickel-Cadmium Cells:

(1) Date Started: 12 September 1967

(2) Test Completed: 7 March 1968

d. Five General Electric, 20 ah, Nickel-Cadmium Cells:

(1) Date Started: 22 January 1969

(2) Test Completed: 19 April 1969

e. Five Genral Electric, 6.0 ah, Nickel-Cadmium Cells:

(1) Date Started: 8 November 1967

(2) Test discontinued 15 November 1967 following rupture of all cells.

f. Five General Electric, 6.0 ah, Nickel-Cadmium Cells:

(1) Date Started: 29 November 1967

(2) Test Completed: 7 March 1968

16. Operation of Silver-Cadmium Batteries in Parallel (Paragraph 16, Enclosure (1)):

a. Date Started: 5 May 1967

b. Initial Number of Cells: 10

c. Cells Remaining on Test: 0

d. Cycles to Failure: 1384

e. Removed from Test: 3 April 1969

17. Synchronous Orbit; G.E. 12 ah, Nickel-Cadmium Cells (Paragraph 17, Enclosure (1)):

a. Date Started: 23 March 1969

b. Initial Number of Cells: 30

c. Cells Remaining on Test: 30

d. Cycles to Date: 221

18. Synchronous Orbit; G.E. 6.0 ah, Nickel-Cadmium Cells (Paragraph 18, Enclosure (1)):

a. Date Started: 19 July 1967

b. Initial Number of Cells: 30

c. Cells Remaining on Test: 25

d. Cycles to Date: 836

e. Five additional cells added 2 August 1968

(1) Cells Remaining on Test: 5

(2) Cycles to Date: 456

19. 5.0 Ampere-Hour, Zinc-Oxygen Cells, manufactured by Union Carbide (Paragraph 19, Enclosure (1)):

a. Date Started: 1 November 1967

b. Initial Number of Cells: 6

c. Cells Remaining on Test: 0

d. Cycles to Completion:

(1) Serial number 791 completed test after 69 cycles.

(2) Serial number 792 completed test after 59 cycles.

(3) Serial number 794 completed test after 51 cycles on 7-19-68.

(4) Serial number 802 completed test after 97 cycles on 8-23-68.

(5) Serial number 803 completed test after 78 cycles on 8-8-68.

(6) Serial number 804 completed test after 50 cycles on 7-19-68.

20. 12 Ampere-Hour, Silver-Cadmium Cells, manufactured by Gulton (Paragraph 20, Enclosure (1)):

a. Date Started: 18 October 1968

b. Initial Number of Cells: 100

c. Ten groups have completed test:

(1) Testing on the last of 10 groups was completed 5 March 1969.