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# EVALUATION PROGRAM

for

# SECONDARY SPACECRAFT CELLS

FOURTH ANNUAL REPORT
OF
CYCLE LIFE TEST

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QUALITY EVALUATION LABORATORY
UNITED STATES NAVAL AMMUNITION DEPOT
CRANE, INDIANA

# EVALUATION PROGRAM FOR SECONDARY SPACECRAFT CELLS

# FOURTH ANNUAL REPORT OF CYCLE LIFE TEST

QE/C 68-138

14 MAY 1968

PREPARED UNDER THE DIRECTION OF

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Enclosure (1)

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C. Pack Identification:

1. Each cell pack in the cycle life test program was assigned a pack number for convenient identification. This number is permanent and uniquely identifies the particular group of cells constituting that pack. For example, the 10 G.E. 3.0 ah cells cycling at 0° C with a 1.5-hour orbit and 15 percent depth of discharge constitute Pack 67A. These numbers were assigned arbitrarily and therefore have no additional significance.

D. Discharge and Charge Currents:

1. All discharges are conducted at specified constant current rates. All charging is done at specified constant current rates until the maximum specified on-charge voltage limit for the respective temperature condition is reached, at which time charging continues at the specified maximum voltage limit with corresponding reduction of the current rate.

2. All currents were based on the manufacturer's rated ampere-hour capacity. The letter c, as used in this report, is a symbol for the rated capacity in ampere-hours. For example, a cell with a rated capacity of 3.0 ampere-hours, used at the 10-hour rate, would have a discharge or charge current equal to c/10 or 300 milli-amperes.

a. The depth of discharge, which is the percent of a cell's rated capacity drawn from the cell, is expressed by the following formula: Discharge Current (Amperes) x Hours = Percent Depth of Discharge x Rated Capacity.

$$I_d \times \text{Hours} = \frac{D}{100} \times c$$

Since the discharges of the 1.5-hour and 3-hour orbit periods are one-half hour long, the discharge current for either orbit period may be found by the simplified formula:

$$I_d = 0.02\ Dc$$

where: $I_d$ = discharge current in amperes
$D$ = percent depth of discharge required
$c$ = rated capacity of the cells.

For example, a pack composed of 3.0 ampere-hour cells, to be discharged to a depth of 15 percent, would require a discharge current $I_d$ of 0.9 amperes ($I_d = 0.02 \times 15 \times 3 = 0.90$ amperes).

b. The percent of recharge is most easily defined operationally as follows: If Qd is the number of ampere-hours to

be removed from the pack on discharge and Qc the number of ampere-hours to be returned on charge, then $Q_c = Q_d$ x Percent of Recharge. Expressed in terms of currents, this becomes $I_c \times T_c = I_d \times T_d \times$ Percent Recharge,

where: $I_c$ = charge current in amperes
$T_c$ = length of charge, in hours
$I_d$ = discharge current in amperes
$T_d$ = length of discharge, in hours.

For example: In the case of a 3.0 ampere-hour pack, 1.5-hour orbit (30 minutes discharge, 60 minutes charge), 15 percent depth of discharge and 115 percent recharge, the charging current would be:

$$I_c = \frac{I_d \times T_d \times \text{Percent Recharge}}{T_c}$$

$$= \frac{(0.02 \times 15 \times 3) \times 0.5 \times 1.15}{1}$$

$$= 0.518 \text{ amperes.}$$

In the case of a 3.0 ampere-hour pack, 3-hour orbit (30 minutes discharge, 150 minutes charge), 25 percent depth of discharge and 125 percent recharge, the charging current would be:

$$I_c = \frac{(0.02 \times 25 \times 3) \times 0.5 \times 1.25}{2.5} = 0.375 \text{ amperes.}$$

3. Figure 1 is a set of typical characteristic voltage and current curves for three 10-cell packs of the same cell type, all on a 1.5-hour orbit period and at 25 percent depth of discharge, but with one pack at 0° C, one at 25° C and one at 40° C.

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QE/C 68-138

# REPORT BRIEF

# CYCLE LIFE TFST

# OF

# SECONDARY SPACECRAFT CELLS

Ref: (a) National Aeronautics and Space Administration Purchase Order Number W11,252B
(b) NASA ltr BRA/VBK/pad of 25 September 1961 w/BUWEPS first end FQ-1:WSK of 2 October 1961 to CO NAD Crane
(c) Preliminary Work Statement for Battery Evaluation Program of 25 August 1961

## I. TEST ASSIGNMENT BRIEF

A. In compliance with references (a) and (b), evaluation of secondary spacecraft cells was begun according to the program outline of reference (c). This fourth annual report covers all of the cycle life test, the third phase of the evaluation program of secondary spacecraft cells, through 17 December 1967. The acceptance tests and general performance tests, the first and second phases of the evaluation program were reported earlier. The purpose of the acceptance tests is to insure that all cells put into the life cycle program meet the specifications outlined in the respective purchase contracts. A limited number of cells of each type (usually five) are subjected to the general performance tests to determine their actual capabilities. These reports may be obtained from NASA, Scientific and Technical Information Facility, College Park, Maryland 20740.

B. The object of this evaluation program is to gather specific information concerning secondary spacecraft cells. Cell performance characteristics and limitations are reported and are used by spacecraft power systems planners, designers and integration teams. Weaknesses in cell design are discovered, reported and used to guide research and development efforts toward improving the reliability of space batteries. Failures encountered in the IMP, NIMBUS, OGO, OAO and other satellite programs have been studied and remedied through special tests performed at NAD Crane in this program.

C. The life cycling test was begun in December 1963.

## II. TEST OUTLINE BRIEF

A. This activity began the cycle life test on 660 sealed, nickel-cadmium cells purchased by the National Aeronautics and Space Administration. The cells were from four manufacturers, and consisted

of seven sample classifications ranging from 3 to 20 ampere-hours. Several types of cells have been added to the original test program. These include nickel-cadmium cells ranging in capacity from 1.25 to 50.0 ampere-hours; silver-cadmium cells ranging in capacity from 5.0 to 12.0 ampere-hours; and silver-zinc cells ranging in capacity from 16.0 to 40.0 ampere-hours. One purpose of the cycle life program is to determine the cycling performance capabilities of packs of cells (5 or 10 cell packs) under different load, charge control and temperature conditions. The load conditions include cycle length (orbit periods) of 1.5, 3.0, 8.0 and 24 hours; depth of discharge ranging from 10 to 75 percent. The charge control methods used are voltage limit, auxiliary electrode, coulometer, stabistor and a two-step regulator. Specially constructed cells to apply internal pressure against the face of the plate stack, and a type to permit high charge rates were also tested. Environmental conditions include ambient temperatures of -20° C, 0° C, 25° C, 40° C, 50° C, and a cycling temperature of 0° to 40° C within a period of 24 hours. A summary of all active and completed packs is listed on the following pages.

| TYPE | AMPERE-HOUR | ORBIT PERIOD | DEPTH OF DISCHARGE | TEMP (°C) | MANUFACTURER | SPECIAL SYMBOL | PACK NO. | PERCENT CHARGE | CHARGE CURRENT | DISCHARGE CURRENT | VOLTAGE LIMIT | NO. CELLS IN PACK | DATE STARTED | CYCLES COMPLETED | DATE FAILED |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NICD | 3.00 | 1.5 | 15% | 0° | GE | | 63A | 115 | 0.52 | 0.90 | 1.55 | 10 | 12-6-63 | 22,023 | |
| NICD | 3.00 | 3.0 | 15% | 0° | GE | | 67A | 115 | 0.21 | 0.90 | 1.55 | 10 | 12-20-63 | 11.068 | |
| NICD | 3.00 | 1.5 | 25% | 0° | GE | | 64A | 115 | 0.86 | 1.50 | 1.55 | 10 | 12-5-63 | 22,525 | |
| NICD | 3.00 | 3.0 | 25% | 0° | GE | | 68A | 115 | 0.34 | 1.50 | 1.55 | 10 | 12-20-63 | 11,280 | |
| NICD | 3.00 | 1.5 | 25% | 25° | GE | | 15A | 125 | 0.94 | 1.50 | 1.49 | 10 | 12-6-63 | 10.382 | 11-6-65 |
| NICD | 3.00 | 3.0 | 25% | 25° | GE | | 19A | 125 | 0.38 | 1.50 | 1.49 | 10 | 12-20-63 | 10,340 | |
| NICD | 3.00 | 1.5 | 40% | 25° | GE | | 16A | 125 | 1.50 | 2.40 | 1.49 | 10 | 12-5-63 | 5,014 | 11-18-64 |
| NICD | 3.00 | 3.0 | 40% | 25° | GE | | 20A | 125 | 0.60 | 2.40 | 1.49 | 10 | 12-20-63 | 5,410 | 1-8-66 |
| NICD | 3.00 | 1.5 | 15% | 40° | GE | | 39A | 160 | 0.72 | 0.90 | 1.45 | 10 | 12-12-63 | 8,109 | 6-19-65 |
| NICD | 3.00 | 3.0 | 15% | 40° | GE | | 43A | 160 | 0.29 | 0.90 | 1.45 | 10 | 12-20-63 | 2,656 | 12-26-64 |
| NICD | 3.00 | 1.5 | 25% | 40° | GE | | 40A | 160 | 1.20 | 1.50 | 1.45 | 10 | 12-12-63 | 2,511 | 7-9-64 |
| NICD | 3.00 | 3.0 | 25% | 40° | GE | | 44A | 160 | 0.48 | 1.50 | 1.45 | 10 | 12-20-63 | 4.487 | 9-14-65 |
| NICD | 5.00 | 1.5 | 15% | 0° | GE | NB | 103A | 110 | 0.83 | 1.50 | 1.49 | 5 | 4-24-65 | 14,835 | |
| NICD | 5.00 | 1.5 | 25% | 0° | GE | NBPT | 107A | 110 | 1.38 | 2.50 | 1.49 | 5 | 6-5-65 | 14,180 | |
| NICD | 5.00 | 1.5 | 15% | 25° | GE | NB | 106A | 120 | 0.90 | 1.50 | 1.49 | 5 | 4-24-65 | 14,860 | |
| NICD | 5.00 | 1.5 | 25% | 25° | GE | NBPT | 104B | 120 | 1.50 | 2.50 | 1.49 | 5 | 6-10-65 | 13,149 | 11-15-67 |
| NICD | 5.00 | 1.5 | 15% | 40° | GE | NB | 113A | 130 | 0.98 | 1.50 | 1.49 | 5 | 4-24-65 | 4,998 | 3-15-66 |
| NICD | 5.00 | 1.5 | 25% | 40° | GE | NBPT | 114A | 130 | 1.63 | 2.50 | 1.49 | 5 | 6-12-65 | 8,273 | 12-19-66 |
| NICD | 12.00 | 1.5 | 15% | 0° | GE | | 110A | 115 | 2.07 | 3.60 | 1.55 | 5 | 1-4-64 | 21.957 | |
| NICD | 12.00 | 3.0 | 15% | 0° | GE | | 111A | 115 | 0.83 | 3.60 | 1.55 | 5 | 1-4-64 | 10,835 | |
| NICD | 12.00 | 1.5 | 25% | 0° | GE | | 124A | 115 | 3.45 | 6.00 | 1.55 | 5 | 1-4-64 | 21,547 | |
| NICD | 12.00 | 3.0 | 25% | 0° | GE | | 125A | 115 | 1.38 | 6.00 | 1.55 | 5 | 1-4-64 | 10,907 | |
| NICD | 12.00 | 1.5 | 25% | 25° | GE | | 82A | 125 | 3.75 | 6.00 | 1.49 | 5 | 1-4-64 | 10,878 | 12-30-65 |
| NICD | 12.00 | 3.0 | 25% | 25° | GE | | 83A | 125 | 1.50 | 6.00 | 1.49 | 5 | 1-4-64 | 10,955 | |
| NICD | 12.00 | 1.5 | 40% | 25° | GE | | 96A | 125 | 6.00 | 9.60 | 1.49 | 5 | 1-4-64 | 4,020 | 10-2-64 |
| NICD | 12.00 | 3.0 | 40% | 25° | GE | | 97A | 125 | 2.40 | 9.60 | 1.49 | 5 | 1-4-64 | 5,002 | 11-8-65 |

| TYPE | AMPERE-HOUR | ORBIT PERIOD | DEPTH OF DISCHARGE | TEMP (°C) | MANUFACTURER | SPECIAL SYMBOL | PACK NO. | PERCENT CHARGE | CHARGE CURRENT | DISCHARGE CURRENT | VOLTAGE LIMIT | NO. CELLS IN PACK | DATE STARTED | CYCLES COMPLETED | DATE FAILED |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NICD | 12.00 | 1.5 | 15% | 40° | GE | | 85A | 160 | 2.88 | 3.60 | 1.45 | 5 | 1-9-64 | 9,710 | 11-8-65 |
| NICD | 12.00 | 3.0 | 15% | 40° | GE | | 86A | 160 | 1.15 | 3.60 | 1.45 | 5 | 1-4-64 | 10,579 | |
| NICD | 12.00 | 1.5 | 25% | 40° | GE | | 99A | 160 | 4.80 | 6.00 | 1.45 | 5 | 1-9-64 | 4,853 | 1-5-65 |
| NICD | 12.00 | 3.0 | 25% | 40° | GE | | 100A | 160 | 1.92 | 6.00 | 1.45 | 5 | 1-4-64 | 4,424 | 9-24-65 |
| NICD | 12.00 | 24.0 | 50% | 25° | GE | | 93A | 115 | 0.52 | 6.00 | 1.45 | 5 | 3-28-64 | 349 | 4-28-65 |
| NICD | 12.00 | 1.5 | 25% | 0° | GE | AE | 60A | | 6.00 | 6.00 | | 5 | 10-6-65 | 5,650 | 10-20-66 |
| NICD | 12.00 | 1.5 | 25% | 25° | GE | AE | 12A | | 6.00 | 6.00 | | 5 | 7-20-65 | 1,698 | 12-1-65 |
| NICD | 12.00 | 1.5 | 40% | 25° | GE | AE | 24A | | 9.60 | 9.60 | | 5 | 10-2-65 | 665 | 11-19-65 |
| NICD | 12.00 | 1.5 | 25% | 0° | GE | AE | 48A | | 9.60 | 9.60 | | 5 | 10-12-65 | 5,110 | 2-10-67 |
| NICD | 12.00 | 1.5 | 25% | 0° | GE | AE | 58A | | 6.00 | 6.00 | | 5 | 1-20-67 | 136 | 2-10-67 |
| NICD | 12.00 | 1.5 | 40% | 0° | GE | AE | 72A | | 6.00 | 6.00 | | 5 | 1-20-67 | 304 | 2-2-67 |
| NICD | 12.00 | 1.5 | 25% | 25° | GE | AE | 12B | | 6.00 | 6.00 | | 5 | 1-6-67 | 404 | 2-10-67 |
| NICD | 12.00 | 1.5 | 40% | 25° | GE | AE | 24B | | 6.00 | 9.60 | | 5 | 1-5-67 | 38 | 2-10-67 |
| NICD | 12.00 | 1.5 | 25% | 40° | GE | AE | 36A | | 6.00 | 6.00 | | 5 | 1-27-67 | 75 | 2-3-67 |
| NICD | 12.00 | 1.5 | 40% | 40° | GE | AE | 34A | | 6.00 | 9.60 | | 5 | 1-27-67 | 65 | 2-3-67 |
| NICD | 3.50 | 1.5 | 15% | 0° | GO | | 51A | 115 | 0.60 | 1.05 | 1.55 | 10 | 12-5-63 | 21,464 | |
| NICD | 3.50 | 3.0 | 15% | 0° | GO | | 55A | 115 | 0.24 | 1.05 | 1.55 | 10 | 12-20-63 | 11,072 | |
| NICD | 3.50 | 1.5 | 25% | 0° | GO | | 52A | 115 | 1.00 | 1.75 | 1.55 | 10 | 12-5-63 | 13,730 | 6-11-66 |
| NICD | 3.50 | 3.0 | 25% | 0° | GO | | 56A | 115 | 0.40 | 1.75 | 1.55 | 10 | 12-20-63 | 11,423 | |
| NICD | 3.50 | 1.5 | 25% | 25° | GO | | 3A | 125 | 1.09 | 1.75 | 1.49 | 10 | 12-6-63 | 4,751 | 10-31-64 |
| NICD | 3.50 | 3.0 | 25% | 25° | GO | | 7A | 125 | 0.44 | 1.75 | 1.49 | 10 | 12-20-63 | 4,173 | 7-26-65 |
| NICD | 3.50 | 1.5 | 40% | 25° | GO | | 4A | 125 | 1.72 | 2.80 | 1.49 | 10 | 12-5-63 | 3,164 | 7-9-64 |
| NICD | 3.50 | 3.0 | 40% | 25° | GO | | 8A | 125 | 0.75 | 2.80 | 1.49 | 10 | 12-20-63 | 2,494 | 11-23-64 |
| NICD | 3.50 | 1.5 | 15% | 40° | GO | | 27A | 160 | 0.84 | 1.05 | 1.45 | 10 | 12-12-63 | 4,485 | 11-4-64 |
| NICD | 3.50 | 3.0 | 15% | 40° | GO | | 31A | 160 | 0.34 | 1.05 | 1.45 | 10 | 12-20-63 | 2,517 | 1-3-65 |
| NICD | 3.50 | 1.5 | 25% | 40° | GO | | 28A | 160 | 1.40 | 1.75 | 1.45 | 10 | 12-12-63 | 1,811 | 5-29-64 |

| TYPE | AMPERE-HOUR | ORBIT PERIOD | DEPTH OF DISCHARGE | TEMP (°C) | MANUFACTURER | SPECIAL SYMBOL | PACK NO. | PERCENT CHARGE | CHARGE CURRENT | DISCHARGE CURRENT | VOLTAGE LIMIT | NO. CELLS IN PACK | DATE STARTED | CYCLES COMPLETED | DATE FAILED |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NICD | 3.50 | 3.0 | 25% | 40° | GO | | 32A | 160 | 0.56 | 1.75 | 1.45 | 10 | 12-20-63 | 975 | 6-10-64 |
| NICD | 20.00 | 1.5 | 15% | 0° | GO | | 84A | 115 | 3.45 | 6.00 | 1.55 | 5 | 1-16-64 | 21,576 | |
| NICD | 20.00 | 3.0 | 15% | 0° | GO | | 80A | 115 | 1.38 | 6.00 | 1.55 | 5 | 1-21-64 | 10,941 | |
| NICD | 20.00 | 1.5 | 25% | 0° | GO | | 98A | 115 | 5.75 | 10.00 | 1.55 | 5 | 1-21-64 | 10,641 | 1-14-66 |
| NICD | 20.00 | 3.0 | 25% | 0° | GO | | 94A | 115 | 2.30 | 10.00 | 1.55 | 5 | 1-24-64 | 10,725 | |
| NICD | 20.00 | 1.5 | 25% | 25° | GO | | 104A | 125 | 6.25 | 10.00 | 1.49 | 5 | 1-16-64 | 2,980 | 8-20-64 |
| NICD | 20.00 | 3.0 | 25% | 25° | GO | | 105A | 125 | 2.50 | 10.00 | 1.49 | 5 | 1-21-64 | 5,690 | 3-17-66 |
| NICD | 20.00 | 1.5 | 40% | 25° | GO | | 118A | 125 | 10.00 | 16.00 | 1.49 | 5 | 2-1-64 | 2,937 | 9-7-64 |
| NICD | 20.00 | 3.0 | 40% | 25° | GO | | 119A | 125 | 4.00 | 16.00 | 1.49 | 5 | 2-1-64 | 1,793 | 9-27-64 |
| NICD | 20.00 | 1.5 | 15% | 40° | GO | | 112A | 160 | 4.80 | 6.00 | 1.45 | 5 | 1-16-64 | 5,213 | 2-15-65 |
| NICD | 20.00 | 3.0 | 15% | 40° | GO | | 108A | 160 | 1.92 | 6.00 | 1.45 | 5 | 1-24-64 | 4,273 | 8-31-65 |
| NICD | 20.00 | 1.5 | 25% | 40° | GO | | 126A | 160 | 8.00 | 10.00 | 1.45 | 5 | 1-16-64 | 1,574 | 5-23-64 |
| NICD | 20.00 | 3.0 | 25% | 40° | GO | | 122A | 160 | 3.20 | 10.00 | 1.45 | 5 | 1-24-64 | 983 | 7-2-64 |
| NICD | 1.25 | 1.5 | 25% | -20° | GU | | 74B | | 1.00 | 0.63 | | 5 | 3-3-66 | 9,772 | |
| NICD | 1.25 | 1.5 | 60% | -20° | GU | | 88D | | 1.00 | 0.63 | | 5 | 3-3-66 | 9,161 | |
| NICD | 1.25 | 1.5 | 25% | 0° | GU | | 108B | | 1.25 | 0.63 | | 5 | 3-4-66 | 10,062 | |
| NICD | 1.25 | 1.5 | 60% | 0° | GU | | 96B | | 1.25 | 1.50 | | 5 | 3-4-66 | 9,746 | |
| NICD | 3.50 | 1.5 | 25% | -20° | GU | | 89C | 110 | 0.96 | 1.75 | 1.56 | 5 | 12-24-66 | 5,459 | |
| NICD | 3.50 | 1.5 | [illegible] | -20° | GU | | 75D | 110 | 1.54 | 2.80 | 1.56 | 5 | 12-24-66 | 4,238 | |
| NICD | 3.50 | 1.5 | 25% | 0° | GU | | 122C | 115 | 1.01 | 1.75 | 1.55 | 5 | 12-24-66 | 5,543 | |
| NICD | 3.50 | 1.5 | 40% | 0° | GU | | 99C | 115 | 1.61 | 2.80 | 1.55 | 5 | 12-24-66 | 5,542 | |
| NICD | 3.50 | 1.5 | 25% | 25° | GU | | 87C | 125 | 1.09 | 1.75 | 1.49 | 5 | 12-23-66 | 5,560 | |
| NICD | 3.50 | 1.5 | 25% | 40° | GU | | 112C | 160 | 1.40 | 1.75 | 1.45 | 5 | 1-2-67 | 5,402 | |
| NICD | 3.50 | 1.5 | 40% | 25° | GU | | 73C | 125 | 1.75 | 2.80 | 1.49 | 5 | 12-23-66 | 5,561 | |
| NICD | 3.60 | 1.5 | 40% | 25° | GU | CLM | 39B | | 3.60 | 2.88 | 1.49 | 10 | 11-11-65 | 5,399 | 12-6-66 |
| NICD | 4.00 | 1.5 | 15% | 0° | GU | CC | 115B | 115 | 0.69 | 1.20 | 1.55 | 5 | 7-25-64 | 18,695 | |

| TYPE | AMPERE-HOUR | ORBIT PERIOD | DEPTH OF DISCHARGE | TEMP (°C) | MANUFACTURER | SPECIAL SYMBOL | PACK NO. | PERCENT CHARGE | CHARGE CURRENT | DISCHARGE CURRENT | VOLTAGE LIMIT | NO. CELLS IN PACK | DATE STARTED | CYCLES COMPLETED | DATE FAILED |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NICD | 4.00 | 1.5 | 25% | 0° | GU | CC | 126B | 115 | 1.15 | 2.00 | 1.55 | 5 | 7-25-64 | 19,128 | |
| NICD | 4.00 | 1.5 | 25% | 25° | GU | CC | 4B | 125 | 1.25 | 2.00 | 1.49 | 5 | 8-4-64 | 18,924 | |
| NICD | 4.00 | 1.5 | 40% | 25° | GU | CC | 14B | 125 | 2.00 | 3.20 | 1.49 | 5 | 8-4-64 | 8,474 | 3-19-66 |
| NICD | 4.00 | 1.5 | 15% | 40° | GU | CC | 28B | 160 | 0.96 | 1.20 | 1.45 | 5 | 8-4-64 | 17,111 | |
| NICD | 4.00 | 1.5 | 25% | 40° | GU | CC | 40B | 160 | 1.60 | 2.00 | 1.45 | 5 | 8-4-64 | 10,360 | 6-22-66 |
| NICD | 4.00 | 1.5 | 25% | -20° | GU | CLM | 40C | | 2.00 | 2.00 | 1.56 | 5 | 3-4-67 | 2 | 3-4-67 |
| NICD | 4.00 | 1.5 | 25% | 0° | GU | CLM | 52B | | 2.00 | 2.00 | 1.48 | 5 | 3-3-67 | 4,490 | |
| NICD | 4.00 | 1.5 | 15% | 25° | GU | CLM | 26C | | 1.20 | 1.20 | 1.44 | 5 | 2-18-67 | 4,689 | |
| NICD | 4.00 | 1.5 | 25% | 25° | GU | CLM | 14C | | 2.00 | 2.00 | 1.44 | 5 | 3-3-67 | 2,428 | 8-8-67 |
| NICD | 4.00 | 1.5 | 40% | 25° | GU | CLM | 37C | | 4.80 | 4.80 | 1.44 | 5 | 3-4-67 | 790 | 5-5-67 |
| NICD | 4.00 | 1.5 | 60% | 25° | GU | CLM | 38D | | 3.20 | 3.20 | 1.44 | 5 | 2-18-67 | 1,927 | 6-27-67 |
| NICD | 4.00 | 1.5 | 25% | 40° | GU | CLM | 39C | | 2.00 | 2.00 | 1.38 | 5 | 3-3-67 | 1,508 | 6-20-67 |
| NICD | 5.00 | 1.5 | 15% | 0° | GU | NB | 117A | 110 | 0.83 | 1.50 | 1.49 | 5 | 5-8-65 | 14,430 | |
| NICD | 5.00 | 1.5 | 25% | 0° | GU | NBPT | 121A | 110 | 1.38 | 2.50 | 1.49 | 5 | 6-5-65 | 14,016 | |
| NICD | 5.00 | 1.5 | 15% | 25° | GU | NB | 120A | 120 | 0.90 | 1.50 | 1.49 | 5 | 5-2-65 | 13,420 | |
| NICD | 5.00 | 1.5 | 25% | 25° | GU | NBPT | 118B | 120 | 1.50 | 2.50 | 1.49 | 5 | 6-10-65 | 8,108 | 11-22-66 |
| NICD | 5.00 | 1.5 | 15% | 40° | GU | NB | 127A | 130 | 0.98 | 1.50 | 1.49 | 5 | 4-29-65 | 10,638 | 5-24-67 |
| NICD | 5.00 | 1.5 | 25% | 40° | GU | NBPT | 128A | 130 | 1.63 | 2.50 | 1.49 | 5 | 6-12-65 | 6,345 | 8-18-66 |
| NICD | 5.60 | 1.5 | 25% | -20° | GU | FRS | 44B | 115 | 1.61 | 2.80 | 1.60 | 5 | 1-2-66 | 11,063 | |
| NICD | 5.60 | 1.5 | 25% | -20° | GU | RS | 32B | 115 | 1.61 | 2.80 | 1.60 | 5 | 1-2-66 | 11,008 | |
| NICD | 5.60 | 1.5 | 25% | 0° | GU | FRS | 100B | 115 | 1.61 | 2.80 | 1.55 | 5 | 12-17-65 | 11,131 | |
| NICD | 5.60 | 1.5 | 25% | 0° | GU | RS | 90C | 115 | 1.61 | 2.80 | 1.55 | 5 | 12-17-65 | 11,238 | |
| NICD | 5.60 | 1.5 | 25% | 25° | GU | FRS | 76B | 125 | 1.75 | 2.80 | 1.49 | 5 | 12-10-65 | 10,954 | |
| NICD | 5.60 | 1.5 | 25% | 25° | GU | RS | 96C | 125 | 1.75 | 2.80 | 1.49 | 5 | 12-10-65 | 9,791 | 9-19-67 |
| NICD | 5.60 | 1.5 | 25% | 40° | GU | FRS | 42B | 160 | 2.24 | 2.80 | 1.45 | 5 | 12-3-65 | 3,798 | 9-10-66 |
| NICD | 5.60 | 1.5 | 25% | 40° | GU | RS | 30B | 160 | 2.24 | 2.80 | 1.45 | 5 | 12-3-65 | 1,275 | 3-8-66 |

| TYPE | AMPERE-HOUR | ORBIT PERIOD | DEPTH OF DISCHARGE | TEMP (°C) | MANUFACTURER | SPECIAL SYMBOL | PACK NO. | PERCENT CHARGE | CHARGE CURRENT | DISCHARGE CURRENT | VOLTAGE LIMIT | NO. CELLS IN PACK | DATE STARTED | CYCLES COMPLETED | DATE FAILED |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NICD | 6.00 | 1.5 | 15% | 0° | GU | | 61A | 115 | 1.04 | 1.80 | 1.55 | 10 | 12-31-63 | 10,146 | 12-17-65 |
| NICD | 6.00 | 3.0 | 15% | 0° | GU | | 65A | 115 | 0.41 | 1.80 | 1.55 | 10 | 12-31-63 | 10,771 | |
| NICD | 6.00 | 1.5 | 25% | 0° | GU | | 62A | 115 | 1.72 | 3.00 | 1.55 | 10 | 12-30-63 | 21,851 | |
| NICD | 6.00 | 3.0 | 25% | 0° | GU | | 66A | 115 | 0.69 | 3.00 | 1.55 | 10 | 12-31-63 | 4,414 | 8-31-65 |
| NICD | 6.00 | 1.5 | 25% | 25° | GU | | 13A | 125 | 1.88 | 3.00 | 1.49 | 10 | 12-31-63 | 4,021 | 11-11-64 |
| NICD | 6.00 | 3.0 | 25% | 25° | GU | | 17A | 125 | 0.75 | 3.00 | 1.49 | 10 | 12-20-63 | 2,885 | 1-31-65 |
| NICD | 6.00 | 1.5 | 25% | 25° | GU | | 14A | 125 | 3.00 | 4.80 | 1.49 | 10 | 12-30-63 | 2,086 | 6-19-64 |
| NICD | 6.00 | 3.0 | 40% | 25° | GU | | 18A | 125 | 1.20 | 4.80 | 1.49 | 10 | 12-31-63 | 1,550 | 8-18-64 |
| NICD | 6.00 | 1.5 | 15% | 40° | GU | | 37A | 160 | 0.14 | 1.80 | 1.45 | 10 | 12-31-63 | 6,064 | 4-14-65 |
| NICD | 6.00 | 3.0 | 15% | 40° | GU | | 41A | 160 | 0.58 | 1.80 | 1.45 | 10 | 12-31-63 | 1,689 | 9-14-64 |
| NICD | 6.00 | 1.5 | 25% | 40° | GU | | 38A | 160 | 2.40 | 3.00 | 1.45 | 10 | 12-30-63 | 1,377 | 5-22-64 |
| NICD | 6.00 | 3.0 | 25% | 40° | GU | | 42A | 160 | 1.20 | 3.00 | 1.45 | 10 | 12-31-63 | 4,133 | 8-23-65 |
| NICD | 6.00 | 24.0 | 50% | 25° | GU | | 79A | 115 | 0.20 | 3.00 | 1.49 | 5 | 3-28-64 | 545 | 10-13-65 |
| NICD | 6.00 | 1.5 | 25% | 0° | GU | IM | 13B | 115 | 1.73 | 3.00 | 1.55 | 5 | 2-22-65 | 15,855 | |
| NICD | 6.00 | 1.5 | 40% | 25° | GU | IM | 18B | 125 | 3.00 | 4.80 | 1.49 | 5 | 2-22-65 | 7,577 | 7-21-66 |
| NICD | 6.00 | 1.5 | 25% | 40° | GU | IM | 38B | 160 | 2.40 | 3.00 | 1.45 | 5 | 2-22-65 | 5,766 | 3-31-66 |
| NICD | 6.00 | 1.5 | 10% | 0° | GU | | 61B | 110 | 0.66 | 1.20 | 1.55 | 10 | 6-7-67 | 2,942 | |
| NICD | 6.00 | 1.5 | 25% | 0° | GU | AE | 59A | | 3.00 | 3.00 | | 5 | 4-15-65 | 13,750 | |
| NICD | 6.00 | 1.5 | 40% | 0° | GU | AE | 71A | | 4.80 | 4.80 | | 5 | 4-15-65 | 5,754 | 5-18-66 |
| NICD | 6.00 | 1.5 | 25% | 25° | GU | AE | 23A | | 3.00 | 3.00 | 1.49 | 5 | 2-5-65 | 15,132 | |
| NICD | 6.00 | 1.5 | 40% | 25° | GU | AE | 11A | | 4.80 | 4.80 | | 5 | 2-5-65 | 7,743 | 7-9-66 |
| NICD | 6.00 | 1.5 | 15% | 40° | GU | AE | 35A | | 1.80 | 1.80 | 1.45 | 5 | 6-28-65 | 12,511 | 11-30-67 |
| NICD | 6.00 | 1.5 | 25% | 40° | GU | AE | 47A | | 3.00 | 3.00 | | 5 | 5-16-65 | 5,521 | 5-11-66 |
| NICD | 6.00 | 1.5 | 15% | * | GU | AE | 60B | | 1.80 | 1.80 | | 5 | 4-25-67 | 3,739 | |
| NICD | 6.00 | 1.5 | 25% | * | GU | AE | 24C | | 3.00 | 3.00 | | 5 | 4-25-67 | 3,729 | |
| NICD | 6.00 | 1.5 | 40% | * | GU | AE | 48B | | 4.80 | 4.80 | | 5 | 4-25-67 | 3,279 | |

* These cells are in an ambient temperature which varies sinusoidally from 0° to 40° C once per 24-hour period.

| TYPE | AMPERE-HOUR | ORBIT PERIOD | DEPTH OF DISCHARGE | TEMP (°C) | MANUFACTURER | SPECIAL SYMBOL | PACK NO. | PERCENT CHARGE | CHARGE CURRENT | DISCHARGE CURRENT | VOLTAGE LIMIT | NO. CELLS IN PACK | DATE STARTED | CYCLES COMPLETED | DATE FAILED |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NICD | 6.00 | 3.0 | 25% | -20° | GU | CLM | 41B | | 3.00 | 3.00 | | 5 | 11-18-66 | 2,825 | |
| NICD | 6.00 | 3.0 | 25% | 0° | GU | CLM | 66B | | 3.00 | 3.00 | | 5 | 11-18-66 | 3,078 | |
| NICD | 6.00 | 3.0 | 25% | 25° | GU | CLM | 18C | | 3.00 | 3.00 | | 5 | 11-18-66 | 2,645 | |
| NICD | 6.00 | 3.0 | 25% | 40° | GU | CLM | 29B | | 3.00 | 3.00 | | 5 | 11-18-66 | 3,014 | |
| NICD | 10.00 | 1.5 | 40% | 25° | GU | AE | 8B | | 5.00 | 5.00 | | 5 | 11-27-67 | 328 | |
| NICD | 10.00 | 1.5 | 40% | 40° | GU | AE | 6B | | 5.00 | 5.00 | | 5 | 11-27-67 | 328 | |
| NICD | 12.00 | 1.5 | 15% | 0° | GU | | 16B | 115 | 2.07 | 3.60 | 1.55 | 5 | 2-20-65 | 15,859 | |
| NICD | 12.00 | 1.5 | 25% | 0° | GU | | 101B | 115 | 3.45 | 6.00 | 1.55 | 5 | 12-19-64 | 16,695 | |
| NICD | 12.00 | 1.5 | 25% | 25° | GU | | 27B | 125 | 3.75 | 6.00 | 1.49 | 5 | 1-28-65 | 14,250 | 9-5-67 |
| NICD | 12.00 | 1.5 | 40% | 25° | GU | | 96B | 125 | 6.00 | 9.60 | 1.49 | 5 | 12-2-64 | 5,152 | 11-9-65 |
| NICD | 12.00 | 1.5 | 15% | 40° | GU | | 78A | 160 | 2.88 | 3.60 | 1.45 | 5 | 12-22-64 | 11,081 | 1-4-66 |
| NICD | 20.00 | 1.5 | 25% | 40° | GU | | 90B | 160 | 8.00 | 10.00 | 1.45 | 5 | 12-5-64 | 5,124 | 11-10-65 |
| NICD | 12.00 | 1.5 | 25% | 0° | GU | AE | 70A | | 6.00 | 6.00 | | 5 | 2-10-67 | 4,826 | |
| NICD | 12.00 | 1.5 | 40% | 0° | GU | AE | 71B | | 6.00 | 9.60 | | 5 | 1-6-67 | 5,234 | |
| NICD | 12.00 | 1.5 | 40% | 25° | GU | AE | 11B | | 6.00 | 9.60 | | 5 | 10-17-66 | 6,457 | |
| NICD | 12.00 | 1.5 | 25% | 40° | GU | AE | 47B | | 6.00 | 6.00 | | 5 | 1-5-67 | 5,027 | |
| NICD | 20.00 | 1.5 | 15% | 0° | GU | | 101A | 115 | 3.45 | 6.00 | 1.55 | 5 | 1-16-64 | 3,631 | 9-20-64 |
| NICD | 20.00 | 3.0 | 15% | 0° | GU | | 102A | 115 | 1.38 | 6.00 | 1.55 | 5 | 1-21-64 | 10,776 | |
| NICD | 20.00 | 1.5 | 25% | 0° | GU | | 115A | 115 | 5.75 | 10.00 | 1.55 | 5 | 1-16-64 | 2,291 | 6-24-64 |
| NICD | 20.00 | 3.0 | 25% | 0° | GU | | 116A | 115 | 2.30 | 10.00 | 1.55 | 5 | 2-11-64 | 10,535 | |
| NICD | 20.00 | 1.5 | 25% | 25° | GU | | 73A | 125 | 6.25 | 10.00 | 1.49 | 5 | 1-16-64 | 7,763 | 6-30-65 |
| NICD | 20.00 | 3.0 | 25% | 25° | GU | | 74A | 125 | 2.50 | 10.00 | 1.49 | 5 | 1-21-64 | 1,755 | 9-27-64 |
| NICD | 20.00 | 1.5 | 40% | 25° | GU | | 87A | 125 | 10.00 | 16.00 | 1.49 | 5 | 2-1-64 | 627 | 4-7-64 |
| NICD | 20.00 | 3.0 | 40% | 25° | GU | | 88A | 125 | 4.00 | 16.00 | 1.49 | 5 | 2-1-64 | 359 | 3-21-64 |
| NICD | 20.00 | 1.5 | 15% | 40° | GU | | 76A | 160 | 1.92 | 6.00 | 1.45 | 5 | 1-18-64 | 9,348 | 10-15-65 |
| NICD | 20.00 | 1.5 | 15% | 40° | GU | | 77A | 160 | 1.92 | 6.00 | 1.45 | 5 | 1-21-64 | 6,032 | 4-20-66 |

| TYPE | AMPERE-HOUR | ORBIT PERIOD | DEPTH OF DISCHARGE | TEMP (°C) | MANUFACTURER | SPECIAL SYMBOL | PACK NO. | PERCENT CHARGE | CHARGE CURRENT | DISCHARGE CURRENT | VOLTAGE LIMIT | NO. CELLS IN PACK | DATE STARTED | CYCLES COMPLETED | DATE FAILED |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NICD | 20.00 | 1.5 | 25% | 40° | GU | | 90A | 160 | 8.00 | 10.00 | 1.45 | 5 | 1-18-64 | 4,045 | 11-12-64 |
| NICD | 20.00 | 3.0 | 25% | 40° | GU | | 91A | 160 | 3.20 | 10.00 | 1.45 | 5 | 1-24-64 | 4,480 | 10-14-65 |
| NICD | 20.00 | 1.5 | 15% | 0° | GU | AE | 58B | | 5.00 | 6.00 | | 5 | 4-8-67 | 3,422 | |
| NICD | 20.00 | 1.5 | 15% | 25° | GU | AE | 12C | | 5.00 | 6.00 | | 5 | 3-9-67 | 4,330 | |
| NICD | 20.00 | 1.5 | 15% | 40° | GU | AE | 36B | | 5.00 | 6.00 | | 5 | 3-11-67 | 2,740 | 9-5-67 |
| NICD | 50.00 | 1.5 | 25% | 0° | GU | | 95A | 115 | 14.38 | 25.00 | 1.55 | 5 | 6-8-64 | 3,227 | 2-9-65 |
| NICD | 50.00 | 1.5 | 15% | 40° | GU | | 123A | 160 | 12.00 | 15.00 | 1.45 | 5 | 6-8-64 | 1,878 | 11-11-64 |
| NICD | 3.90 | 1.5 | 25% | 0° | NIFE | | 97C | 107 | 1.07 | 2.00 | 1.50 | 5 | 9-29-67 | 1,274 | |
| NICD | 3.90 | 1.5 | 25% | 25° | NIFE | | 85C | 107 | 1.07 | 2.00 | 1.50 | 5 | 9-29-67 | 1,274 | |
| NICD | 3.00 | 1.5 | 15% | 0° | SO | 3S | 43B | 115 | 0.52 | 0.90 | 1.55 | 5 | 6-24-65 | 13,430 | |
| NICD | 3.00 | 1.5 | 25% | 0° | SO | 3S | 31B | 115 | 0.96 | 1.50 | 1.55 | 5 | 6-24-65 | 13,108 | |
| NICD | 3.00 | 1.5 | 25% | 25° | SO | 3S | 3B | 125 | 0.94 | 1.50 | 1.49 | 5 | 6-25-65 | 11,726 | 8-23-67 |
| NICD | 3.00 | 1.5 | 40% | 25° | SO | 3S | 2B | 125 | 1.50 | 2.40 | 1.49 | 5 | 7-10-65 | 5,399 | 7-26-66 |
| NICD | 3.00 | 1.5 | 15% | 40° | SO | 3S | 26B | 160 | 0.72 | 0.90 | 1.45 | 5 | 7-10-65 | 6,285 | 10-4-66 |
| NICD | 3.00 | 1.5 | 25% | 40° | SO | 3S | 37B | 160 | 1.20 | 1.50 | 1.45 | 5 | 7-10-65 | 5,625 | 8-4-66 |
| NICD | 3.50 | 1.5 | 10% | 0° | SO | | 15B | 110 | 0.39 | 0.70 | 1.55 | 10 | 6-7-67 | 2,999 | |
| NICD | 5.00 | 1.5 | 15% | 0° | SO | | 49A | 115 | 0.86 | 1.50 | 1.55 | 10 | 12-31-63 | 22,213 | |
| NICD | 5.00 | 3.0 | 15% | 0° | SO | | 53A | 115 | 0.35 | 1.50 | 1.55 | 10 | 12-31-63 | 10,981 | |
| NICD | 5.00 | 1.5 | 25% | 0° | SO | | 50A | 115 | 1.44 | 2.50 | 1.55 | 10 | 12-17-63 | 21,577 | |
| NICD | 5.00 | 3.0 | 25% | 0° | SO | | 54A | 115 | 0.58 | 2.50 | 1.55 | 10 | 12-31-63 | 10,952 | |
| NICD | 5.00 | 1.5 | 25% | 25° | SO | | 1A | 125 | 1.56 | 2.50 | 1.49 | 10 | 12-17-63 | 11,745 | 2-27-66 |
| NICD | 5.00 | 3.0 | 25% | 25° | SO | | 5A | 125 | 0.62 | 2.50 | 1.49 | 10 | 12-31-63 | 10,664 | |
| NICD | 5.00 | 1.5 | 40% | 25° | SO | | 2A | 125 | 2.50 | 4.00 | 1.49 | 10 | 12-17-63 | 6,671 | 4-24-65 |
| NICD | 5.00 | 3.0 | 40% | 25° | SO | | 6A | 125 | 1.00 | 4.00 | 1.49 | 10 | 1-2-64 | 5,211 | 12-13-65 |
| NICD | 5.00 | 1.5 | 15% | 40° | SO | | 25A | 160 | 1.20 | 1.50 | 1.45 | 10 | 12-17-63 | 9,328 | 10-31-65 |
| NICD | 5.00 | 3.0 | 15% | 40° | SO | | 29A | 160 | 0.48 | 1.50 | 1.45 | 10 | 12-31-63 | 5,975 | 4-17-66 |

| | TYPE | AMPERE-HOUR | ORBIT PERIOD | DEPTH OF DISCHARGE | TEMP (°C) | MANUFACTURER | SPECIAL SYMBOL | PACK NO. | PERCENT CHARGE | CHARGE CURRENT | DISCHARGE CURRENT | VOLTAGE LIMIT | NO. CELLS IN PACK | DATE STARTED | CYCLES COMPLETED | DATE FAILED |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | NICD | 5.00 | 1.5 | 25% | 40° | SO | | 26A | 160 | 2.00 | 2.50 | 1.45 | 10 | 12-17-63 | 3,625 | 10-15-64 |
| | NICD | 5.00 | 3.0 | 25% | 40° | SO | | 30A | 160 | 0.80 | 2.50 | 1.45 | 10 | 12-31-63 | 4,141 | 8-7-65 |
| | NICD | 5.00 | 1.5 | 25% | -20° | SO | ST | 75C | | 5.00 | 2.50 | | 5 | 10-24-65 | 2,145 | 4-5-66 |
| | NICD | 5.00 | 1.5 | 40% | -20° | SO | ST | 39B | | 5.00 | 4.00 | | 5 | 10-24-65 | 1,530 | 2-26-66 |
| | NICD | 5.00 | 1.5 | 25% | 0° | SO | ST | 92A | | 5.00 | 2.50 | | 5 | 9-5-65 | 3,774 | 5-24-67 |
| | NICD | 5.00 | 1.5 | 40% | 0° | SO | ST | 122B | | 5.00 | 4.00 | | 5 | 9-5-65 | 5,190 | 9-24-66 |
| | NICD | 5.00 | 1.5 | 25% | 25° | SO | ST | 73B | | 5.00 | 2.50 | | 5 | 8-12-65 | 3,742 | 4-15-66 |
| | NICD | 5.00 | 1.5 | 40% | 25° | SO | ST | 87B | | 5.00 | 4.00 | | 5 | 8-12-65 | 2,392 | 1-27-66 |
| | NICD | 5.00 | 1.5 | 25% | 40° | SO | ST | 99B | | 5.00 | 2.50 | | 5 | 8-23-65 | 4,388 | 7-9-66 |
| | NICD | 5.00 | 1.5 | 15% | 40° | SO | ST | 112B | | 5.00 | 1.50 | | 5 | 8-23-65 | 3,294 | 4-1-66 |
| | NICD | 5.00 | 1.5 | 25% | 25° | SO | AE | 14D | | 2.50 | 1.47 | 1.50 | 5 | 11-7-67 | 518 | |
| | NICD | 20.00 | 1.5 | 25% | 25° | SO | | 22A | | 20.00 | 10.00 | 1.50 | 10 | 9-20-67 | 599 | |
| × | NICD | 20.00 | 1.5 | 25% | 25° | SO | | 10A | 140 | 7.00 | 10.00 | 1.49 | 10 | 9-20-67 | 1,414 | |
| | NICD | 20.00 | 1.5 | 40% | 25° | SO | | 34B | | 20.00 | 16.00 | 1.50 | 10 | 9-20-67 | 1,239 | |
| | NICD | 20.00 | 3.0 | 40% | 25° | SO | | 46A | | 20.00 | 16.00 | 1.50 | 10 | 9-20-67 | 462 | |
| | NICD | 20.00 | 1.5 | 75% | 25° | SO | | 72B | | 20.00 | 30.00 | 1.50 | 10 | 9-20-67 | 905 | |
| | AGCD | 8.00 | 8.0 | 25% | 25° | ESB | AE | 1B | 175 | 0.50 | 2.00 | 1.51 | 5 | 9-9-66 | 1,346 | |
| | AGCD | 3.00 | 1.5 | 16% | 25° | YD | | 2C | 260 | 1.30 | 1.00 | 1.52 | 9 | 9-16-66 | 7,039 | 12-12-67 |
| | AGCD | 5.00 | 24.0 | 20% | 0° | YD | C3SP | 57B | | 0.30 | 1.00 | 1.50 | 5 | 9-17-65 | 267 | 6-17-66 |
| | AGCD | 5.00 | 24.0 | 20% | 25° | YD | C3SP | 21A | | 0.30 | 1.00 | 1.50 | 5 | 9-17-65 | 98 | 12-25-65 |
| | AGCD | 5.00 | 24.0 | 20% | 40° | YD | C3SP | 45A | | 0.30 | 1.00 | 1.50 | 5 | 9-27-65 | 61 | 11-16-65 |
| | AGCD | 5.00 | 24.0 | 20% | 25° | YD | RCPSP | 9C | | 1.00 | 10.00 | 1.50 | 10 | 10-27-65 | 34 | 12-1-65 |
| | AGCD | 5.00 | 24.0 | 20% | 25° | YD | CPSP | 33B | | 0.30 | 1.00 | 1.49 | 5 | 10-17-65 | 764 | |
| | AGCD | 5.00 | 24.0 | 20% | 25° | YD | PLSP | 69A | | 0.30 | 1.00 | 1.50 | 5 | 10-27-65 | 610 | 7-17-67 |
| | AGCD | 5.00 | 8.0 | 20% | 0° | YD | | 114B | | 0.30 | 1.00 | 1.50 | 5 | 1-22-67 | 954 | |
| | AGCD | 5.00 | 24.0 | 20% | 0° | YD | | 113B | | 0.30 | 1.00 | 1.50 | 5 | 1-22-67 | 328 | |

| TYPE | AMPERE-HOUR | ORBIT PERIOD | DEPTH OF DISCHARGE | TEMP (°C) | MANUFACTURER | SPECIAL SYMBOL | PACK NO. | PERCENT CHARGE | CHARGE CURRENT | DISCHARGE CURRENT | VOLTAGE LIMIT | NO. CELLS IN PACK | DATE STARTED | CYCLES COMPLETED | DATE FAILED |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AGCD | 5.00 | 8.0 | 20% | 25° | YD | | 118C | | 0.30 | 1.00 | 1.50 | 5 | 1-17-67 | 970 | |
| AGCD | 5.00 | 24.0 | 20% | 25° | YD | | 77B | | 0.30 | 1.00 | 1.50 | 5 | 1-12-67 | 339 | |
| AGCD | 5.00 | 24.0 | 20% | 25° | YD | | 105B | | 0.30 | 1.00 | 1.50 | 5 | 1-12-67 | 77 | 4-19-67 |
| AGCD | 5.00 | 24.0 | 20% | 40° | YD | | 128B | | 0.30 | 1.00 | 1.50 | 5 | 1-19-67 | 269 | 11-4-67 |
| AGCD | 10.00 | 8.0 | 30% | 25° | YD | | 45D | 117 | 0.50 | 3.00 | 1.51 | 5 | 5-3-67 | 729 | |
| AGCD | 11.00 | 24.0 | 40% | 0° | YD | | 45B | 157 | 0.30 | 4.40 | 1.51 | 10 | 11-5-66 | 121 | 3-13-67 |
| AGCD | 11.00 | 24.0 | 40% | 25° | YD | | 21B | 157 | 0.30 | 4.40 | 1.51 | 10 | 11-5-66 | 69 | 1-13-67 |
| AGCD | 11.00 | 8.0 | 27% | 25° | YD | PLSP | 21C | 117 | 0.50 | 3.00 | 1.51 | 5 | 3-28-67 | 37 | 4-9-67 |
| AGCD | 11.00 | 8.0 | 27% | 25° | YD | WNSP | 45C | 117 | 0.50 | 3.00 | 1.51 | 5 | 3-28-67 | 70 | 4-22-67 |
| AGCD | 12.00 | 24.0 | 50% | 0° | YD | | 57A | | 0.60 | 6.00 | 1.50 | 10 | 2-14-64 | 168 | 9-3-64 |
| AGCD | 12.00 | 24.0 | 50% | 40° | YD | | 33A | | 0.60 | 6.00 | 1.50 | 10 | 2-14-64 | 210 | 9-20-64 |
| AGCD | 12.00 | 1.5 | 25% | -20° | YD | | 85B | 130 | 3.90 | 6.00 | 1.60 | 5 | 1-19-66 | 2,375 | 3-25-67 |
| AGCD | 12.00 | 1.5 | 25% | 0° | YD | | 97B | 130 | 3.90 | 6.00 | 1.58 | 5 | 1-19-66 | 4,481 | 3-15-67 |
| AGCD | 12.00 | 1.5 | 25% | 25° | YD | | 82B | 130 | 3.90 | 6.00 | 1.55 | 5 | 1-17-66 | 4,559 | 11-27-66 |
| AGCD | 12.00 | 24.0 | 43% | 0° | YD | AE-GE | 21D | | 0.50 | 5.20 | 1.51 | 5 | 6-16-67 | 61 | 8-14-67 |
| AGCD | 12.00 | 24.0 | 43% | 40° | YD | AE-GE | 9F | | 0.50 | 5.20 | 1.51 | 5 | 6-16-67 | 185 | |
| AGZN | 25.00 | 24.0 | 40% | 25° | DL | | 89A | | 15.00 | 10.00 | 1.97 | 5 | 9-18-64 | 80 | 12-3-64 |
| AGZN | 25.00 | 24.0 | 40% | 25° | DL | | 75A | | 15.00 | 10.00 | 1.97 | 5 | 8-18-64 | 32 | 9-18-64 |
| AGZN | 25.00 | 3.0 | 40% | 25° | DL | | 88B | | 15.00 | 20.00 | 1.97 | 5 | 3-1-65 | 120 | 3-16-65 |
| AGZN | 25.00 | 3.0 | 40% | 25° | DL | | 88C | | 15.00 | 20.00 | 1.97 | 5 | 3-26-65 | 325 | 5-6-65 |
| AGZN | 25.00 | 24.0 | 40% | 25° | DL | 2SR | 9D | | 1.00 | 10.00 | 1.97 | 10 | 12-13-65 | 121 | 4-18-66 |
| AGZN | 25.00 | 24.0 | 40% | 25° | DL | 2SR | 9E | | 1.00 | 10.00 | 1.97 | 10 | 10-5-66 | 90 | 1-4-67 |
| AGZN | 40.00 | 24.0 | 25% | 25° | DL | | 75B | | 25.00 | 10.00 | 1.97 | 5 | 10-28-64 | 139 | 3-15-65 |
| AGZN | 12.00 | 24.0 | 42% | 25° | YD | | 9A | | 0.50 | 5.00 | 1.97 | 10 | 5-7-65 | 58 | 7-7-65 |
| AGZN | 16.00 | 24.0 | 31% | 25° | YD | 2SR | 57C | | 0.50 | 5.00 | 2.00 | 10 | 12-2-66 | 391 | |

# SECTION I

## CYCLE LIFE TEST OF SECONDARY SPACECRAFT CELLS

### I. INTRODUCTION

A. Considerable research is being done to find more efficient and reliable means of storing electrical energy for orbiting satellites and similar applications. Rechargeable cells offer one such means. The test program at NAD Crane has been established in order to further the evaluation of certain types of cells and to obtain performance and failure data as an aid to their continued improvement.

B. This fourth annual report summarizes the cycle life test work through 17 December 1967 including that contained in NAD Crane reports QE/C 64-274 of 15 June 1964, QE/C 65-356 of 14 May 1965, QE/C 66-304 of 13 May 1966 and QE/C 67-685 of 3 November 1967 with the exception of the graphs on data that was gathered before or during 1966. The cycle life test is the third phase of the evaluation program of secondary spacecraft cells. The acceptance tests and the general performance tests, the first two phases of this program, were reported earlier.

C. On 5 December 1963 this activity began the cycle life test on 660 of the 1100 sealed nickel-cadmium cells purchased by National Aeronautics and Space Administration (NASA). The cells are from four manufacturers, and consist of seven sample classifications ranging from 3.0 to 20 ampere-hours.

D. The purpose of the cycle program is to determine the cycling performance capabilities of packs of cells under different load and temperature conditions. The load conditions include cycle lengths (orbit periods) of 1.5 hours and 3 hours, and depths of discharge ranging from 15 to 40 percent. Environmental conditions include ambient temperatures of 0° C, 25° C, 40° C and 50° C with normal atmospheric conditions. The packs are cycled until more than half of the cells of each pack have failed.

E. Section I, paragraphs I through IV, of this report refers only to the original 660 nickel-cadmium cells. Cells and tests added to the original program are covered in section II of this report.

### II. CELL DESCRIPTION

A. General: Photograph 1 is a group picture of the seven cell types.

1. General Electric Company (G.E.):

a. 3.0 Ampere-hour: The cell container and the cell cover are made of stainless steel. The positive terminal is insulated from the cell cover by a ceramic (titanium hydride) bushing and protrudes through the bushing with a solder tab welded to the terminal. The negative terminal is a solder tab welded to the cover.

b. 12.0 Ampere-hour: The cell container and the cell cover are made of stainless steel. Both terminals are insulated from the cell cover by ceramic seals and protrude as 1/4-20 threaded posts.

2. Gould-National Batteries, Inc. (Gould):

a. 3.5 Ampere-hour: The cell container and the cell cover are made of stainless steel and serve as the positive terminal. The negative terminal is a pigtail type extension of the negative plate tab through the center of the cover. The negative terminal is insulated from the "positive" cover by a glass to metal seal.

b. 20.0 Ampere-hour: The cell container and the cell cover are made of stainless steel. Each of the terminals is insulated from the can by a nylon seal and protrudes as a 1/4-28 threaded post. The cells, equipped with pressure relief valves instead of being sealed as specified, were returned to the manufacturer to be sealed after completion of the acceptance tests. The manufacturer sealed the cells by encasing each individual cell in a mold of epoxy resin.

3. Gulton Industries, Inc. (Gulton):

a. 6.0 Ampere-hour: The cell container and the cell cover are made of stainless steel. The positive terminal is insulated from the cell cover by a ceramic seal, while the negative terminal is welded to the cover. Both are solder type terminals.

b. 20.0 Ampere-hour: The cell container and the cell cover are made of stainless steel. Both terminals are insulated from the cell cover by ceramic seals and protrude through the cover as solder type terminals.

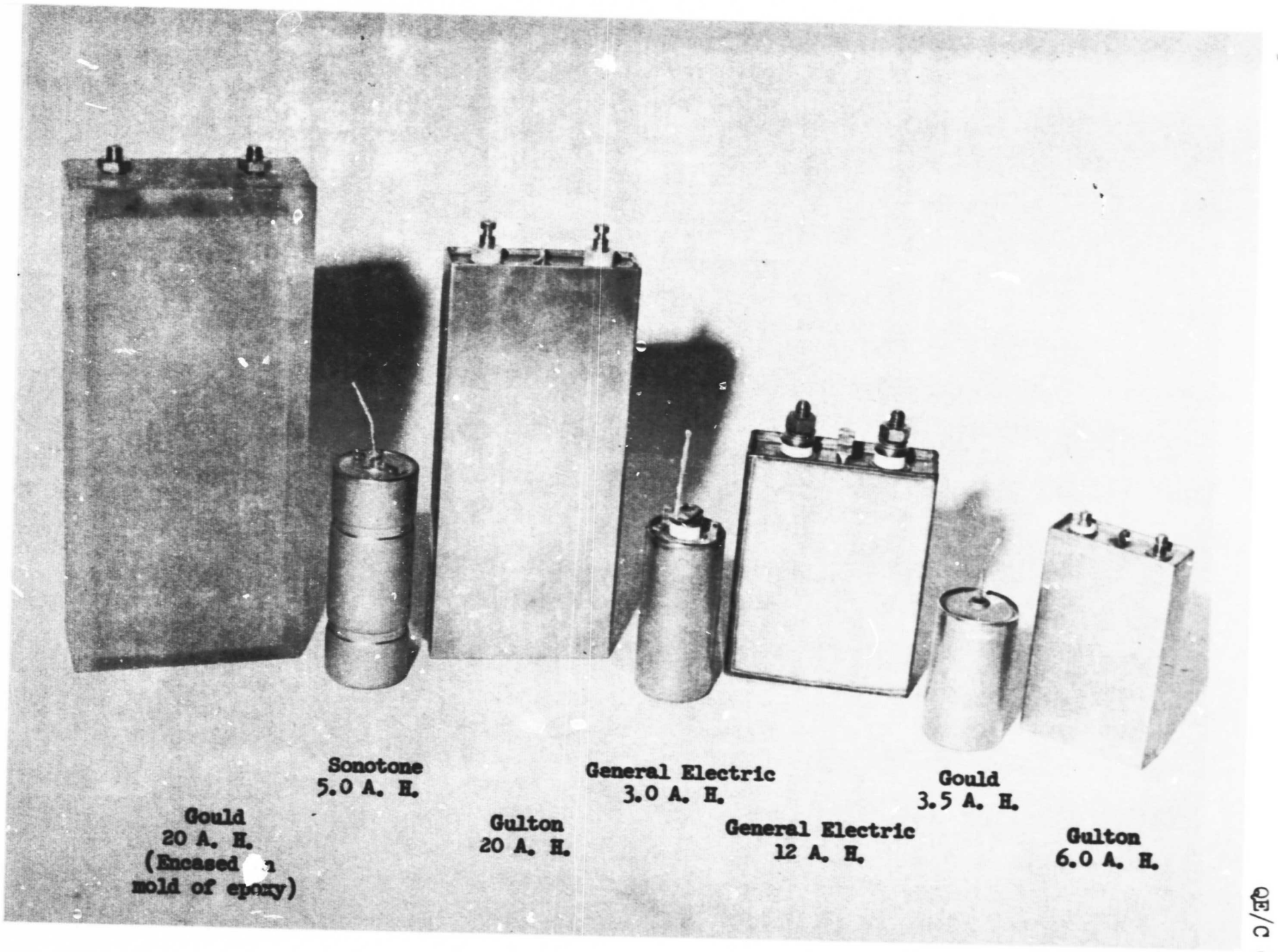
4. Sonotone Corporation (Sonotone):

a. 5.0 Ampere-hour: The cell container and the cell cover are made of stainless steel. Two stainless steel tabs, welded to the cover, serve as contacts for the negative terminal. The positive terminal is a solder type extension of the positive plate tab through the center of the cover. The positive terminal is

insulated from the "negative" cover by a glass to metal seal. Two ring indentations, about 1/32 inch deep, located approximately 7/8 inch from either end of the cell can, were crimped after cell assembly to hold the element snugly in the cylindrical can.

B. Dimensions and Weight:

1. The dimensions, weight and case polarity for each of the seven types of cells are tabulated in Table I.




Group Picture of Cell Types

PHOTOGRAPH 1

TABLE I

PHYSICAL CHARACTERISTICS OF CELLS

| Manufacturer and Manufacturer's Rated Capacity | Shape | Average Dimensions (Inches) Height Base to Top of Terminal | Width or Diameter | Length or Depth | Average Weight (Grams) | Case Polarity |
|---|---|---|---|---|---|---|
| G.E. 3.0 ah | Cylindrical | 3.10 | 1.25 D | -- | 155.0 | Negative |
| Gould 3.5 ah | Cylindrical | 2.22 | 1.28 D | -- | 135.2 | Positive |
| Sonotone 5.0 ah | Cylindrical | 3.67 | 1.31 D | -- | 237.4 | Negative |
| Gulton 6.0 ah | Rectangular | 3.68 | 2.09 W | 0.81 | 267.0 | Negative |
| G.E. 12.0 ah | Rectangular | 4.59 | 3.02 W | 1.11 | 562.0 | -- |
| Gould 20.0 ah | Rectangular | *7.95 | 3.05 W | 0.97 | 1045.0 | -- |
| | | **8.10 | 3.56 W | 1.49 | 1423.0 | -- |
| Gulton 20.0 ah | Rectangular | 7.10 | 2.98 W | 0.90 | 871.6 | -- |

* Before Epoxy Cover

** After Epoxy Cover

## III. DESCRIPTION OF CYCLE TEST

A. These tests are a study of the effects of the cycle period, environmental temperature, percent of recharge, and depth of discharge on the cycle life of the test samples.

B. Test Parameters:

1. The program includes a total of 12 combinations of test parameters. Cells, of comparable capacities, of each of the seven types were grouped into packs, with one pack of each type per combination of parameters. Each of the 84 packs thus obtained continues cycling at its particular combination of parameters until it has failed.

2. The 3.0 ampere-hour (ah), 3.5 ah, 5.0 ah and 6.0 ah packs consist of 10 cells each. The 12 ah and 20 ah packs consist of five cells each.

3. The test parameters are as follows:

a. Three environmental temperatures, with corresponding percentages of recharge.

(1) 0° ± 2° C, with 115 percent recharge.

(2) 25° ± 2° C, with 125 percent recharge.

(3) 40° ± 2° C, with 160 percent recharge.

b. At each of the three temperatures, two depths of discharge.

(1) At 0° C, 15 and 25 percent depths of discharge.

(2) At 25° C, 25 and 40 percent depths of discharge.

(3) At 40° C, 15 and 25 percent depths of discharge.

c. Two orbit periods for all three temperatures.

(1) 1.5 hours (30 minutes of discharge, 60 minutes of charge).

(2) 3 hours (30 minutes of discharge, 150 minutes of charge).

d. Voltage limits on charge were specified according to temperature and were chosen to inhibit internal generation of

gas. They are expressed as average voltages per cell for the entire pack.

(1) At 0° C, 1.55 ± 0.03 volts per cell, average.

(2) At 25° C, 1.49 ± 0.03 volts per cell, average.

(3) At 40° C, 1.45 ± 0.03 volts per cell, average.

4. Cycling at 50° C.

a. Initially, the test temperatures were 0°, 25° and 50° C, with the 50° C voltage limit on charge set at 1.41 ± 0.03 volts per cell, average.

b. The 28 packs assigned to the high temperature environment began cycling at 50° C, but after a short period of cycling it became apparent that the majority of these packs would not continue to cycle satisfactorily at that temperature. For all but four of these 28 packs, the ambient temperature was therefore reduced from 50° C to 40° C, and shortly thereafter the charge voltage limit was raised from 1.41 ± 0.03 volts per cell to 1.45 ± 0.03 volts per cell.

c. The remaining four packs were left cycling at the original 50° C, in order to obtain more information about performance at that temperature, with the reservation that they be likewise changed to a 40° C ambient temperature whenever they ceased to function satisfactorily. All were cycling at 25 percent depth of discharge. All four were eventually changed to 40° C, and have since failed.

d. Considerations for cycling at 50° C and results are discussed more fully in paragraph IV.C.

5. Table II is a summary chart of all test conditions.

## TABLE II

### SUMMARY OF TEST PARAMETERS

For each orbit period, one pack of each of the seven cell types is cycling at each of the six temperature-depth of discharge combinations.

| ORBIT PERIODS: 1.5 Hours and 3 Hours | | | | | |
|---|---|---|---|---|---|
| Discharge Time | Charge Time | Temperature °C | Percent Recharge | Percent Depth of Discharge | On-Charge Voltage Limit Avg./Active Cell |
| 30 Minutes | 60 Minutes and 2.5 Hours | (50*) | (160**) | (15) (25) | (1.41) |
| | | 40 | 160 | 15 25 | 1.41 (Changed to 1.45) |
| | | 25 | 125 | 25 40 | 1.49 |
| | | 0 | 115 | 15 25 | 1.55 |

* All packs changed to 40° C ambient.

** One pack of Gulton 6.0 ah cells at 50° C was temporarily raised to 200 percent recharge, but this was not sufficient to maintain normal cycling.

C. Pack Identification:

1. Each cell pack in the cycle life test program was assigned a pack number for convenient identification. This number is permanent and uniquely identifies the particular group of cells constituting that pack. For example, the 10 G.E. 3.0 ah cells cycling at 0° C with a 1.5-hour orbit and 15 percent depth of discharge constitute Pack 63A. These numbers were assigned arbitrarily and therefore have no additional significance.

D. Discharge and Charge Currents:

1. All discharges are conducted at specified constant current rates. All charging is done at specified constant current rates until the maximum specified on-charge voltage limit for the respective temperature condition is reached, at which time charging continues at the specified maximum voltage limit with corresponding reduction of the current rate.

2. All currents were based on the manufacturer's rated ampere-hour capacity. The letter c, as used in this report, is a symbol for the rated capacity in ampere-hours. For example, a cell with a rated capacity of 3.0 ampere-hours, used at the 10-hour rate, would have a discharge or charge current equal to c/10 or 300 milli-amperes.

a. The depth of discharge, which is the percent of a cell's rated capacity drawn from the cell, is expressed by the following formula: Discharge Current (Amperes) x Hours = Percent Depth of Discharge x Rated Capacity.

$$I_d \times \text{Hours} = \frac{D}{100} \times c$$

Since the discharges of the 1.5-hour and 3-hour orbit periods are one-half hour long, the discharge current for either orbit period may be found by the simplified formula:

$$I_d = 0.02\ Dc$$

where: $I_d$ = discharge current in amperes
$D$ = percent depth of discharge required
$c$ = rated capacity of the cells.

For example, a pack composed of 3.0 ampere-hour cells, to be discharged to a depth of 15 percent, would require a discharge current $I_d$ of 0.9 amperes ($I_d = 0.02 \times 15 \times 3 = 0.90$ amperes).

b. The percent of recharge is most easily defined operationally as follows: If Qd is the number of ampere-hours to

be removed from the pack on discharge and Qc the number of ampere-hours to be returned on charge, then $Q_c = Q_d$ x Percent of Recharge. Expressed in terms of currents, this becomes $I_c \times T_c = I_d \times T_d \times$ Percent Recharge,

where: $I_c$ = charge current in amperes
$T_c$ = length of charge, in hours
$I_d$ = discharge current in amperes
$T_d$ = length of discharge, in hours.

For example: In the case of a 3.0 ampere-hour pack, 1.5-hour orbit (30 minutes discharge, 60 minutes charge), 15 percent depth of discharge and 115 percent recharge, the charging current would be:

$$I_c = \frac{I_d \times T_d \times \text{Percent Recharge}}{T_c}$$

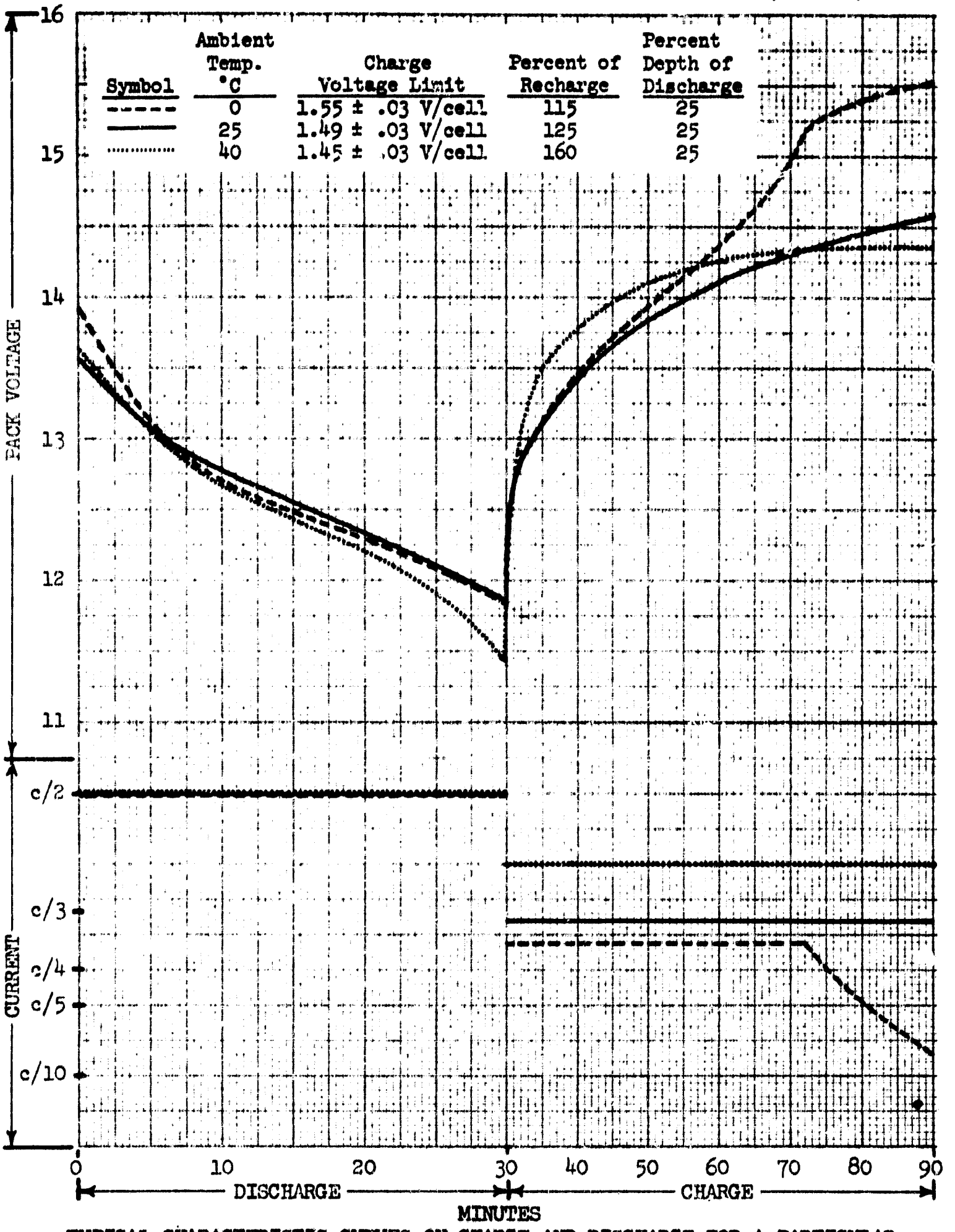
$$= \frac{(0.02 \times 15 \times 3) \times 0.5 \times 1.15}{1}$$

$$= 0.518 \text{ amperes.}$$

In the case of a 3.0 ampere-hour pack, 3-hour orbit (30 minutes discharge, 150 minutes charge), 25 percent depth of discharge and 125 percent recharge, the charging current would be:

$$I_c = \frac{(0.02 \times 25 \times 3) \times 0.5 \times 1.25}{2.5} = 0.375 \text{ amperes.}$$

3. Figure 1 is a set of typical characteristic voltage and current curves for three 10-cell packs of the same cell type, all on a 1.5-hour orbit period and at 25 percent depth of discharge, but with one pack at 0° C, one at 25° C and one at 40° C.




TYPICAL CHARACTERISTIC CURVES ON CHARGE AND DISCHARGE FOR A PARTICULAR ORBIT PERIOD, DEPTH OF DISCHARGE, AND CELL TYPE

FIGURE 1

E. Physical Preparation of Cells.

1. Pack Arrangement: The cells of each manufacturer type were connected in series into 5-cell or 10-cell packs. Within each pack, the cells were given numbers from 1 to 5 or from 1 to 10, for identification of their relative electrical and physical positions. These are shown in Figure 2.

a. G.E.:

(1) 3.0 Ampere-hour (10-cell Pack): Each cell was wrapped in a double layer of 0.003 inch polyethylene sheet and arranged into oval shaped packs held together with tape, according to diagram (a) of Figure 2. The electrical leads were soldered to the terminals on the top of the cells. The cells are cycling in the vertical position.

(2) 12.0 Ampere-hour (5-cell Pack): The cells were arranged in line between two 1/4-inch steel plates and held together with four 1/4-inch steel bolts. The cells were insulated from each other and the end plates by a layer of 0.015 inch insulating paper between two layers of 0.003 inch polyethylene sheet. The electrical connections were made at screw terminals on the tops of the cells. The cells are cycling in the vertical position.

b. Gould:

(1) 3.5 Ampere-hour (10-cell Pack): Each cell was wrapped in a double layer of 0.003 inch polyethylene sheet and arranged into triangular packs held together with tape, according to diagram (b) of Figure 2. The pigtail lead extending from the center of the top is the negative terminal. Since the case is positive, a tab was soldered to the base of each cell. The series electrical connections were made by soldering the pigtail negative terminal lead of one cell to the tab at the base of an adjoining cell. The cells are cycling in a horizontal position.

(2) 20.0 Ampere-hour (5-cell Pack): The cells were arranged in line between two 1/8-inch steel plates and held together with four 1/4-inch steel bolts. The cells were insulated from each other by a double layer of 0.003 inch polyethylene sheet. The electrical connections were made at the screw terminals on the tops of the cells. The cells are cycling in the vertical position.

c. Gulton:

(1) 6.0 Ampere-hour (10-cell Pack): The cells were arranged in line between two 1/4-inch steel plates and held together with four 1/4-inch steel bolts, as in diagram (d) of Figure 2. The

cells were insulated from each other and from the end plates by a layer of 0.015 inch insulating paper between two layers of 0.003 inch polyethylene sheet. The electrical leads were soldered to the terminals on the tops of the cells. The cells are cycling in the vertical position.

(2) 20.0 Ampere-hour (5-cell Pack): The cells were arranged in line between two 1/4-inch steel plates and held together with four 1/4-inch steel bolts. The cells were insulated from each other and from the end plates by a double layer of 0.003 inch polyethylene sheet. The electrical leads were soldered to the terminals at the tops of the cells. The cells are cycling in the vertical position.

d. Sonotone:

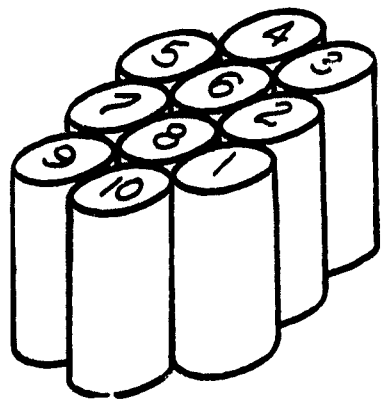
(1) 5.0 Ampere-hour (10-cell Pack): Each cell was wrapped in a double layer of 0.003 inch polyethylene sheet and arranged into oval shaped packs held together with tape, according to diagram (c) of Figure 2. The electrical leads were soldered to the terminals on the tops of the cells. The cells are cycling in the vertical position.

2. Temperature Monitoring:

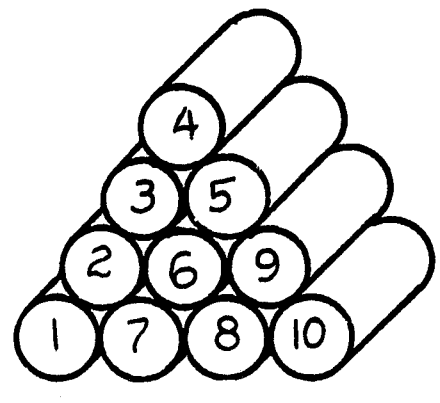
a. A thermocouple (Iron-Constantan, type J) was soldered to the positive terminal of each cell under test.

(1) In the Gould 3.5 ampere-hour cells, the case being the positive terminal, the thermocouple was soldered to the tab previously soldered to the base of the cell.

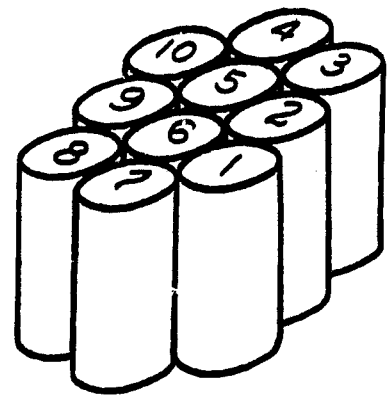
(2) Thermocouple voltages were read simultaneously with cell voltages.



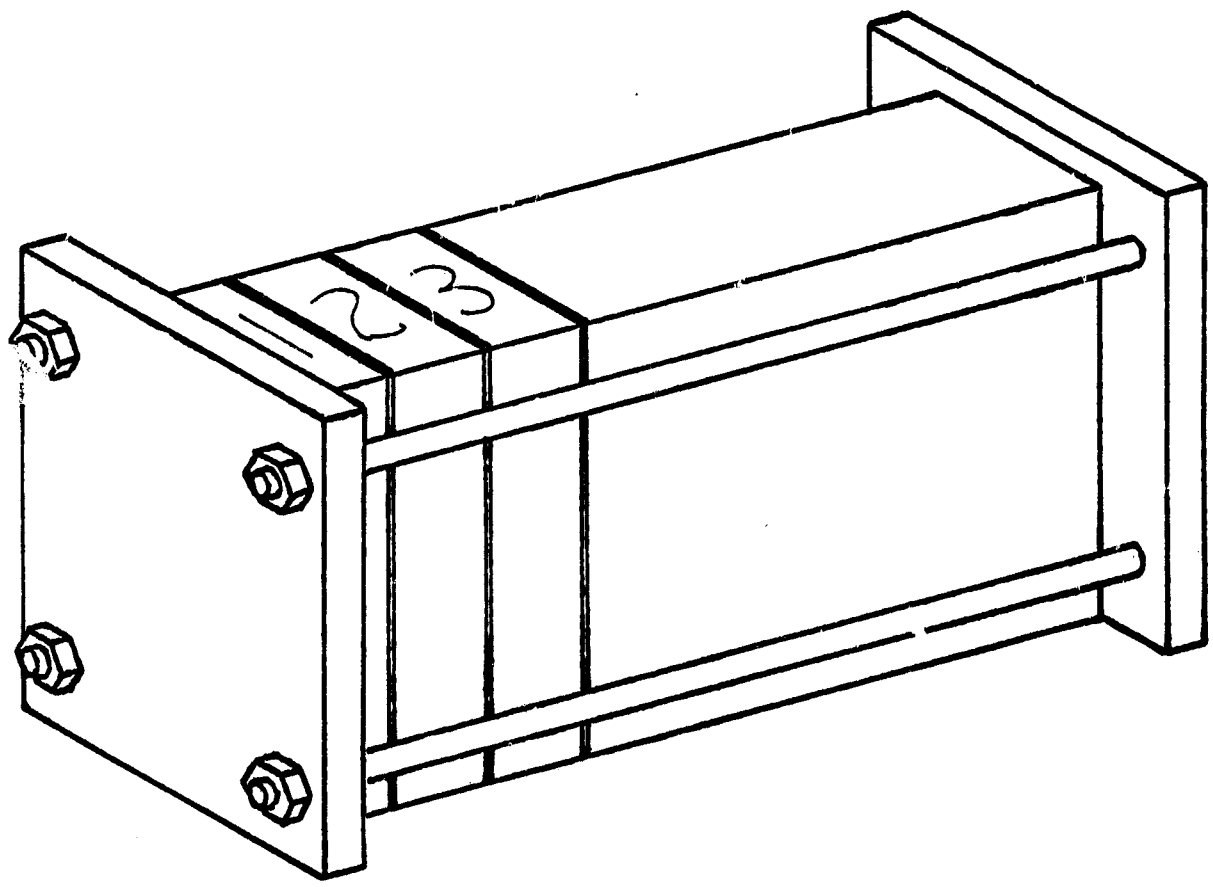

a. G.E. 3.0 ah




b. Gould 3.5 ah




c. Sonotone 5.0 ah




d. All Rectangular Cells

DIAGRAM OF PACK ARRANGEMENTS
(Numbers identify cell position and electrical sequence)

FIGURE 2

F. Recording and Processing of Data.

1. Frequency of Data Recording: The individual cell and pack voltages, currents, and individual cell and ambient temperatures for each measured cycle are recorded at the following designated intervals.

a. During Charge: The readings during the charge period of the 1.5-hour orbit were recorded at 10-minute intervals and at 1 minute after start and 1 minute before the end of charge. The readings during the charge period of the 3-hour orbit were recorded at the 10-minute, 30-minute and each succeeding 20-minute point and at 1 minute after start and 1 minute before the end of charge.

b. During Discharge: The readings during the discharge period of both the 1.5-hour and the 3-hour orbit periods were recorded at 5-minute intervals, and at 1 minute after start and 1 minute before the end of the discharge.

c. Data was taken and recorded during the first cycle and at approximate intervals of 32 cycles. This data was also recorded whenever a possible cell or pack failure was indicated.

2. Data Processing: The data is typed on continuous form paper while succeeding readings are recorded on punched paper tape. The data is then converted to absolute values and stored on nine track, one-half inch magnetic tape according to pack and cycle number.

G. Measurements of Ampere-hour Capacity.

1. Preconditioning of Test Cells.

a. Prior to start of the cycling program, all packs were preconditioned at their designated cycling temperatures as described below. In each case, the on-charge voltage limit was the same as set for the cycling program.

b. After all packs were discharged at the c/2 rate, the cells were equalized to zero voltage by short circuiting across their terminals. They were then recharged at the c/10 rate for 24 hours; except packs of Gulton cells which, in accordance with the manufacturer's recommendations, were recharged at the c/40 rate for 40 hours. This recharge was followed by a discharge at the c/2 rate to a cutoff of 1.0 volt per cell average or to a low of 0.5 volt on any one cell, whichever occurred first. The packs were then recharged at the c/10 rate for 16 hours and discharged at the c/2 rate to the above cutoff point. Any cell showing a significantly low capacity on this second discharge, which would limit the pack's performance on cycling, was replaced and the second charge and

discharge repeated on the entire pack. (The ampere-hour capacities thus obtained for each pack are shown in Tables VIIa through VIIg and the greatest ampere-hour capacities are shown in Figures 12(A) through 12(G).)

(1) Immediately before the start of cycling, each pack was given a 24-hour charge at the c/10 rate.

2. Preconditioning at Change from 50° C to 40° C Ambient Temperature.

a. The packs which were changed from the 50° C to the 40° C ambient temperature were preconditioned again, at the lower temperature. They were first discharged beyond the normal cutoff voltage and the cells equalized to zero voltage by short circuiting across their terminals. Each pack was then recharged for 24 hours at the c/10 rate with the pack voltage limited to an equivalent of 1.41 volts per cell. The packs were then discharged according to the original preconditioning procedure, with the exception that cells showing low capacities were not replaced. (The ampere-hour capacities on this discharge are given in Tables VIIa through VIIg.)

(1) Immediately before the start of cycling at 40° C each pack was given a 24-hour charge at the c/10 rate.

3. Periodic Capacity Checks.

a. The ampere-hour capacity of each pack, at its specified test temperature, was measured after completion of approximately each 88 days of continuous cycling. This is equivalent to about every 1400 cycles for the 1.5-hour orbit periods and every 700 cycles for the 3-hour orbit periods.

b. During the capacity checks, the on-charge voltage limit was the same as for cycling. Each pack being checked was discharged immediately after the end of the regular cycle charge period, at the c/2 rate to a cutoff of 1.0 volt per cell average or to a low of 0.5 volt on any one cell, whichever occurred first. The pack was then recharged at the c/10 rate for 16 hours and discharged again as above. (For those capacity checks which have been completed as of this report, the ampere-hours delivered on both discharges are given in Table VIIa through VIIg.)

c. Before being returned to regular cycling, the pack was given a 48-hour charge at the c/10 rate, with the regular on charge cycling voltage limit.

H. Cell Failures; Failure Criteria.

1. A cell is considered a failure when the terminal voltage drops below 0.5 volt at any time during a regular discharge-charge cycle. It is removed from the pack upon completion of the recorded cycle.

2. A pack is considered a failure when more than one-half of its cells have failed.

IV. TEST RESULTS

A. Current Status; Pack Failures.

1. The number of cycles completed as of 17 December 1967 by the 26 packs which have not failed varies because of different starting times and temporary shutdowns of individual packs for cell removal, or for equipment maintenance. The number of days of continuous cycling completed, at 16 cycles or 8 cycles per day for the 1.5-hour and 3-hour orbit respectively, ranges from 1263 days to 1428 days.

2. A total of 58 of the original 84 packs have failed, the earliest being the Gulton 20 ah packs cycling at 25° C and 40 percent depth of discharge, after 39.2 and 44.8 days of 1.5-hour and 3-hour cycles respectively (Packs 87A and 88A).

3. The number of cycles and the number of days of continuous cycling completed by each pack are given in Table III. An asterisk indicates that the pack had failed as of the given cycle.

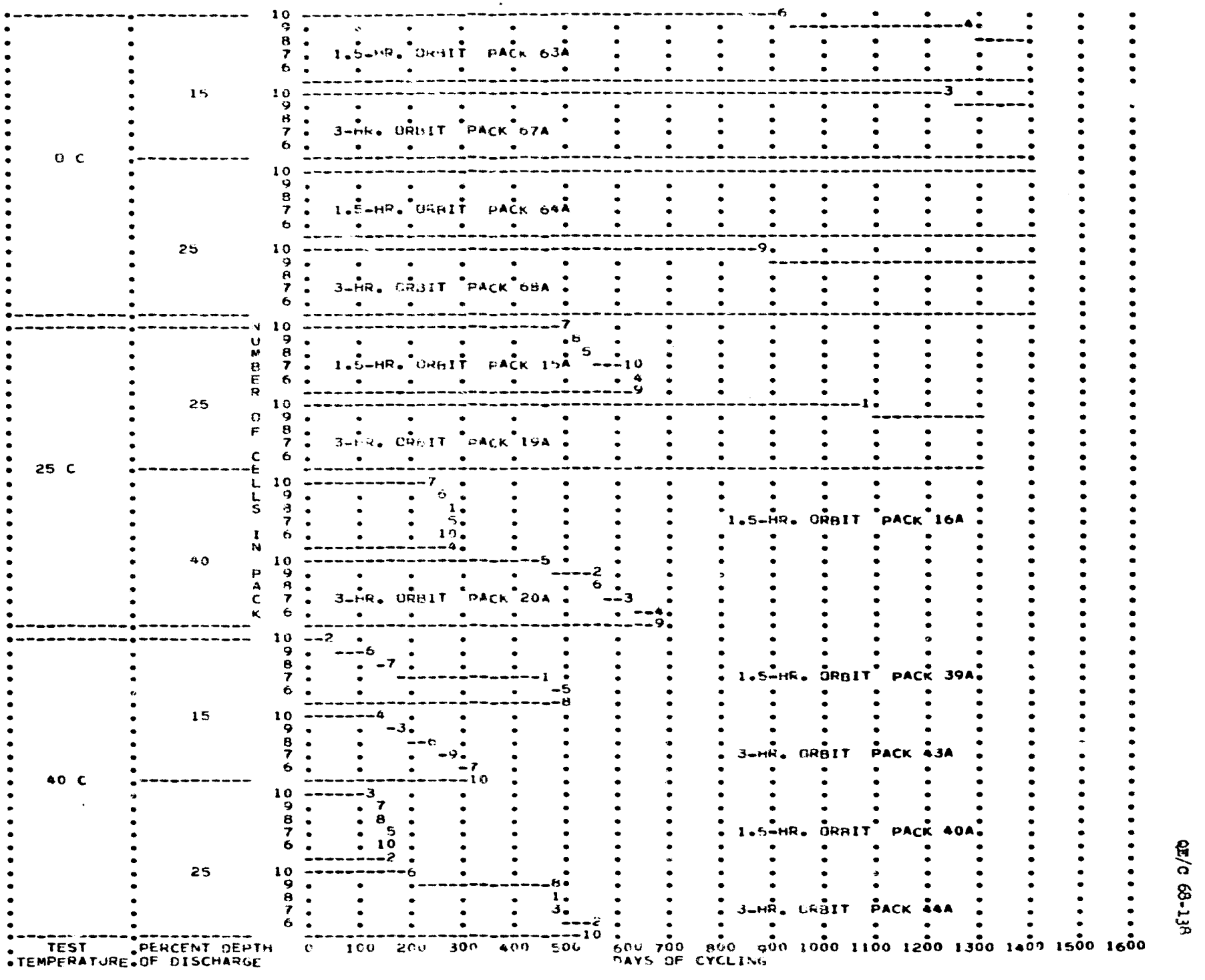
4. Figures 3(A) through 3(G) are profiles showing cell failures and status of each pack in terms of days of continuous cycling. The numbers appearing on the profile are the position numbers of the failed cells. An open space at the end of the profile indicates that the pack is still cycling.

TABLE III

CYCLES AND DAYS OF CYCLING COMPLETED AS OF 31 DECEMBER 1966

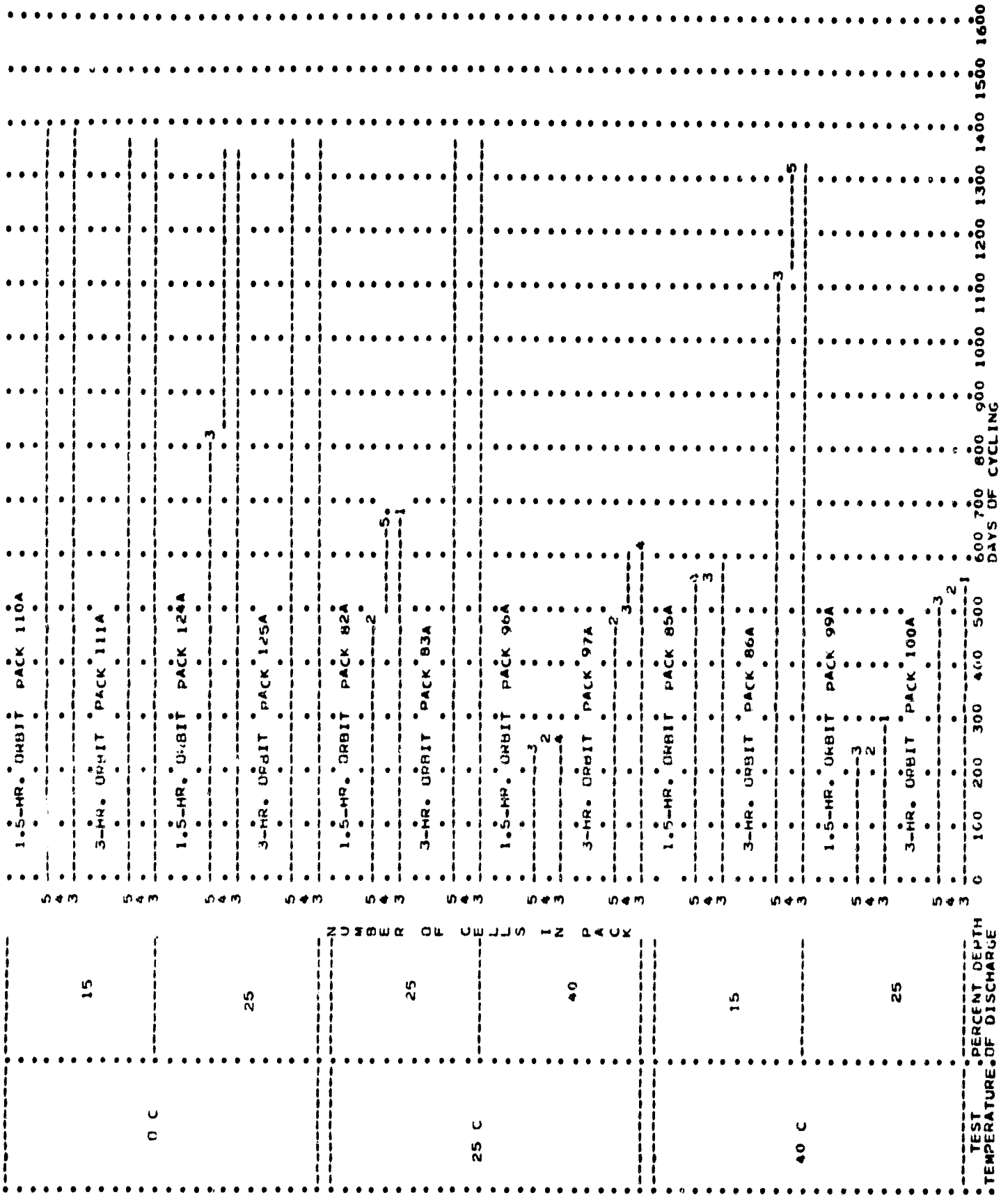
| Test Temperature | Depth of Discharge | Orbit Period (hours) | G.E. 3 ah | | | G.E. 12 ah | | | GOULD 3.5 ah | | | GOULD 20 ah | | | GULTON 6 ah | | | GULTON 20 ah | | | SONOTONE 5 ah | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Pack Number | Cycles | Days of Cycling | Pack Number | Cycles | Days of Cycling | Pack Number | Cycles | Days of Cycling | Pack Number | Cycles | Days of Cycling | Pack Number | Cycles | Days of Cycling | Pack Number | Cycles | Days of Cycling | Pack Number | Cycles | Days of Cycling |
| 0° C | 15% | 1.5 | 63A | 22023 | 1376 | 110A | 21957 | 1372 | 51A | 21464 | 1342 | 84A | 21576 | 1349 | 61A | 10146* | 634 | 101A | 3629* | 227 | 49A | 22213 | 1263 |
| | | 3 | 67A | 11068 | 1384 | 111A | 10835 | 1354 | 55A | 11072 | 1384 | 80A | 10941 | 1368 | 65A | 10781 | 1348 | 102A | 10776 | 1348 | 53A | 10992 | 1374 |
| | 25% | 1.5 | 64A | 22525 | 1408 | 124A | 21574 | 1347 | 52A | 13728* | 858 | 98A | 10641* | 665 | 62A | 21851 | 1366 | 115A | 2291* | 143 | 50A | 21577 | 1349 |
| | | 3 | 68A | 11280 | 1410 | 125A | 10970 | 1363 | 56A | 11423 | 1428 | 94A | 10725 | 1341 | 66A | 4414* | 552 | 116A | 10535 | 1317 | 54A | 10952 | 1369 |
| 25° C | 25% | 1.5 | 15A | 10382* | 649 | 82A | 10878* | 680 | 3A | 4751* | 297 | 104A | 2980* | 186 | 13A | 4021* | 251 | 73A | 7763* | 485 | 1A | 11745* | 734 |
| | | 3 | 19A | 10340 | 1291 | 83A | 10955 | 1369 | 7A | 4173* | 522 | 105A | 5690* | 711 | 17A | 2885* | 361 | 74A | 1754* | 219 | 5A | 11664 | 1333 |
| | 40% | 1.5 | 16A | 5014* | 313 | 96A | 4020* | 251 | 4A | 3164* | 198 | 118A | 2937* | 184 | 14A | 2086* | 130 | 87A | 627* | 39 | 2A | 6671* | 417 |
| | | 3 | 20A | 5410* | 676 | 97A | 5002* | 625 | 8A | 2494* | 312 | 119A | 1793* | 224 | 18A | 1550* | 194 | 88A | 358* | 45 | 6A | 5211* | 651 |
| 50° - 40° C | 15% | 1.5 | 39A | 8109* | 507 | 85A | 9710* | 607 | 27A | 4485* | 280 | 112A | 5213* | 326 | 37A | 6064* | 379 | 76A | 9348* | 584 | 25A | 9328* | 583 |
| | | 3 | 43A | 2656* | 332 | 86A | 10579 | 1322 | 31A | 2517* | 315 | 108A | 4273* | 534 | 41A | 1689* | 211 | 77A | 6032* | 754 | 29A | 5975* | 747 |
| | 25% | 1.5 | 40A | 2511* | 157 | 99A | 4853* | 303 | 28A | 1811* | 113 | 126A | 1569* | 98 | 38A | 1377* | 86 | 90A | 4045* | 253 | 26A | 3625* | 227 |
| | | 3 | 44A | 4487* | 561 | 100A | 4424* | 553 | 32A | 975* | 122 | 122A | 983* | 123 | 42A | 4133* | 517 | 91A | 4480* | 560 | 30A | 4141* | 518 |

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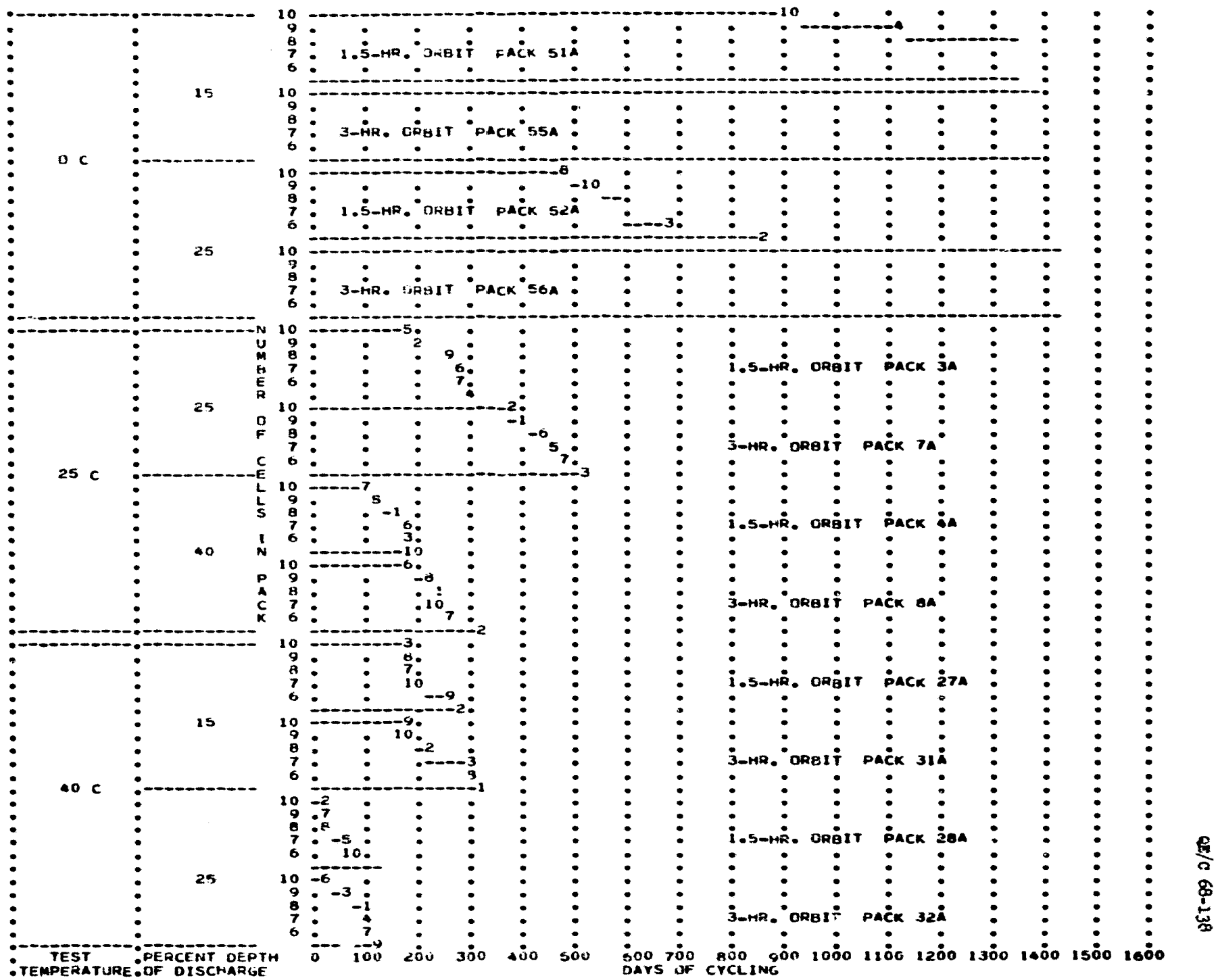

STATUS OF LIFE-CYCLING TEST CELL FAILURES AND DAYS OF CYCLING COMPLETED G.E. 3.0 A.H.

FIGURE 3(A)




STATUS OF LIFE-CYCLING TEST CELL FAILURES AND DAYS OF CYCLING COMPLETED G.E. 12.0 A.H.

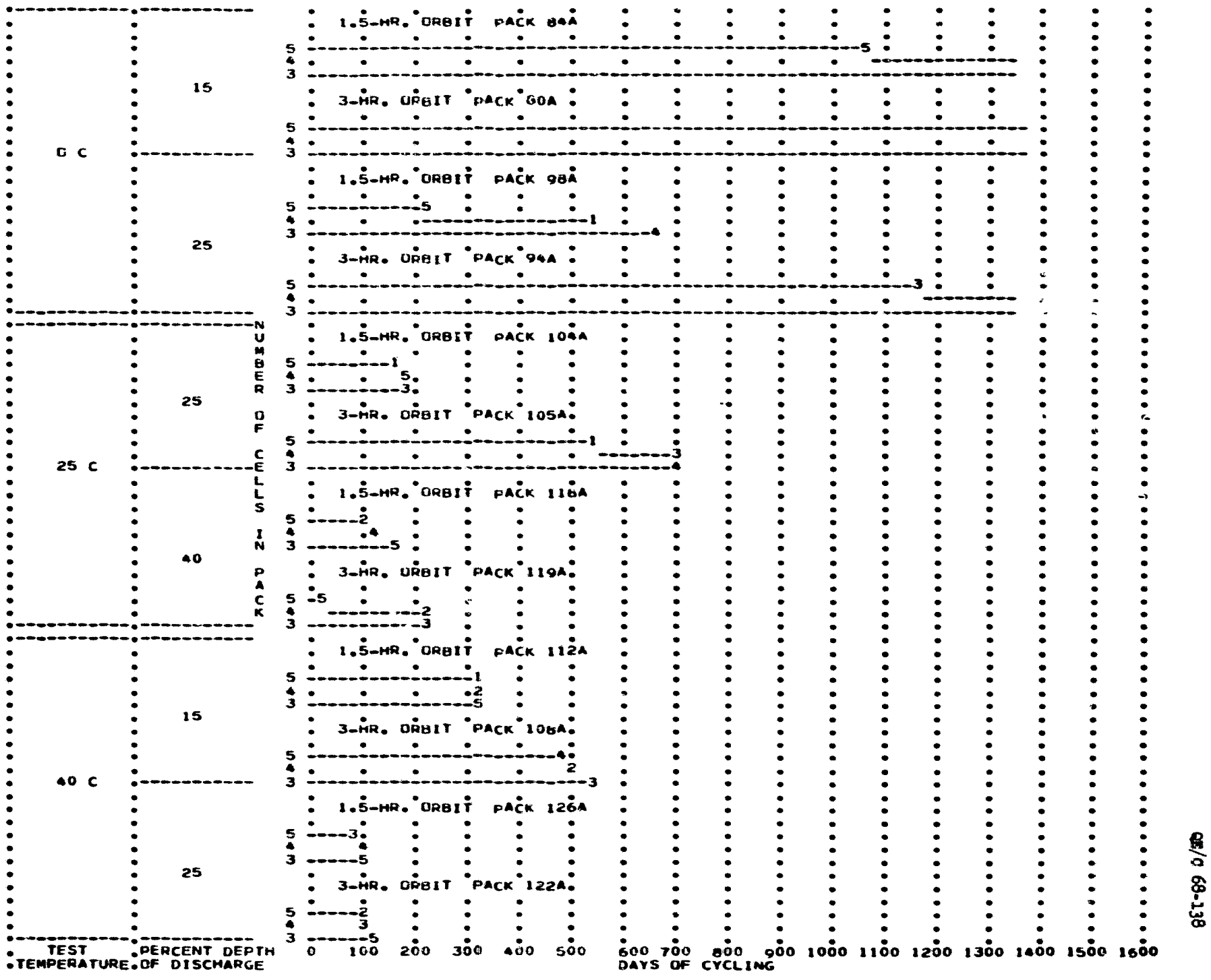
FIGURE 3(B)




STATUS OF LIFE-CYCLING TEST CELL FAILURES AND DAYS OF CYCLING COMPLETED GOULD 3.5 A.H.

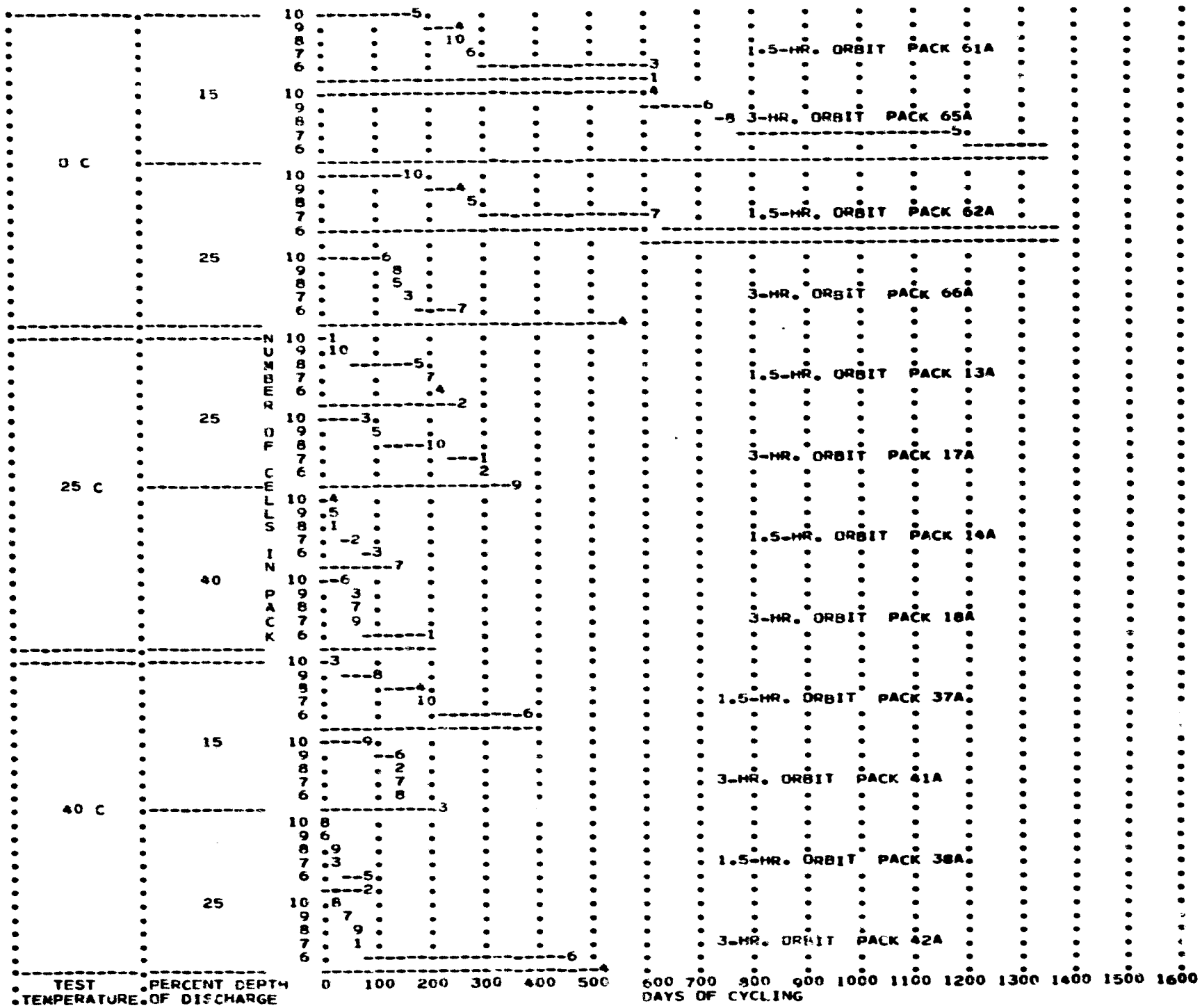
FIGURE 3(c)

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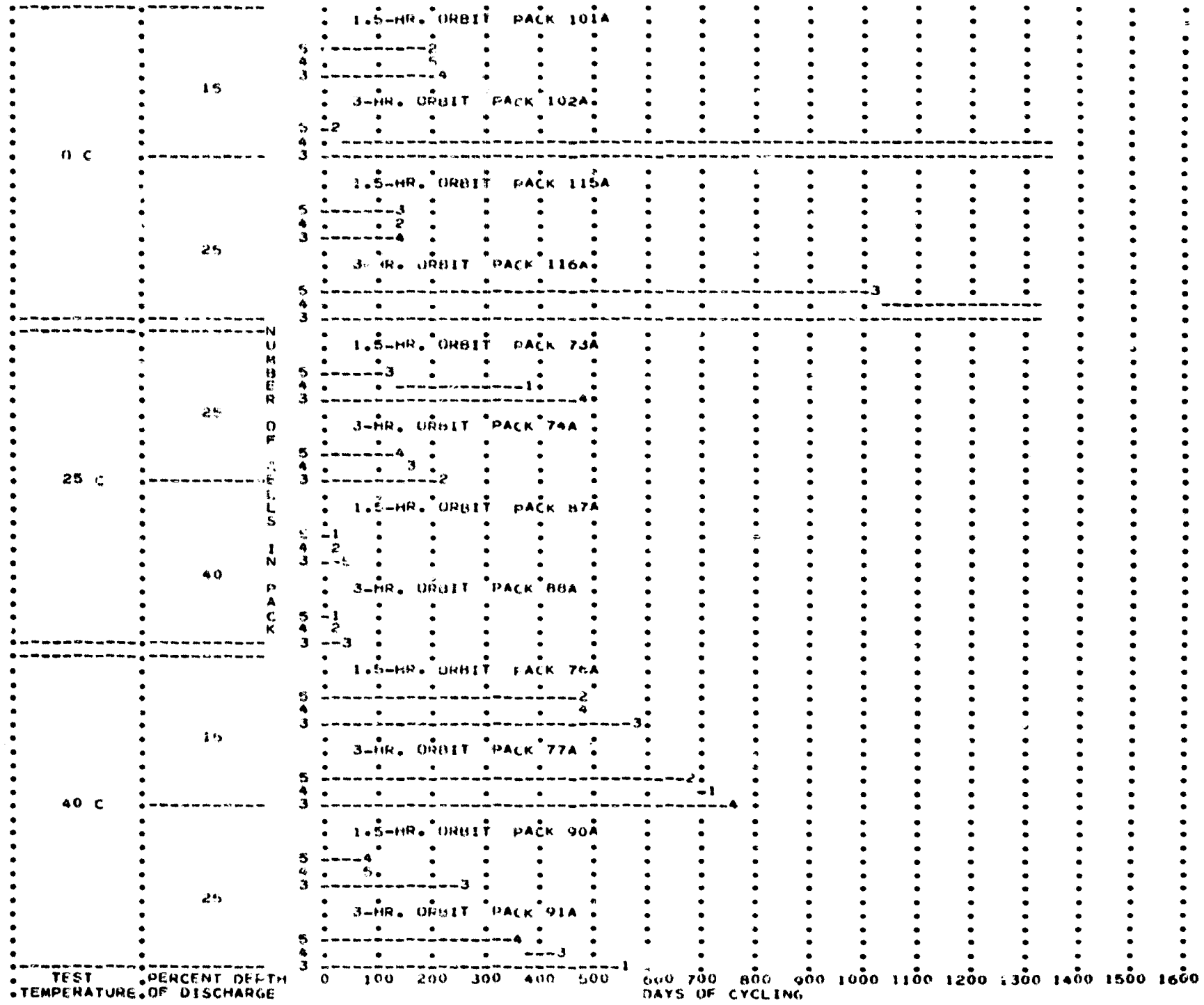

STATUS OF LIFE-CYCLING TEST CELL FAILURES AND DAYS OF CYCLING COMPLETED GOULD 20.0 A.H.

FIGURE 3(D)




STATUS OF LIFE-CYCLING TEST CELL FAILURES AND DAYS OF CYCLING COMPLETED GULTON 6.0 A.H.

FIGURE 3(E)

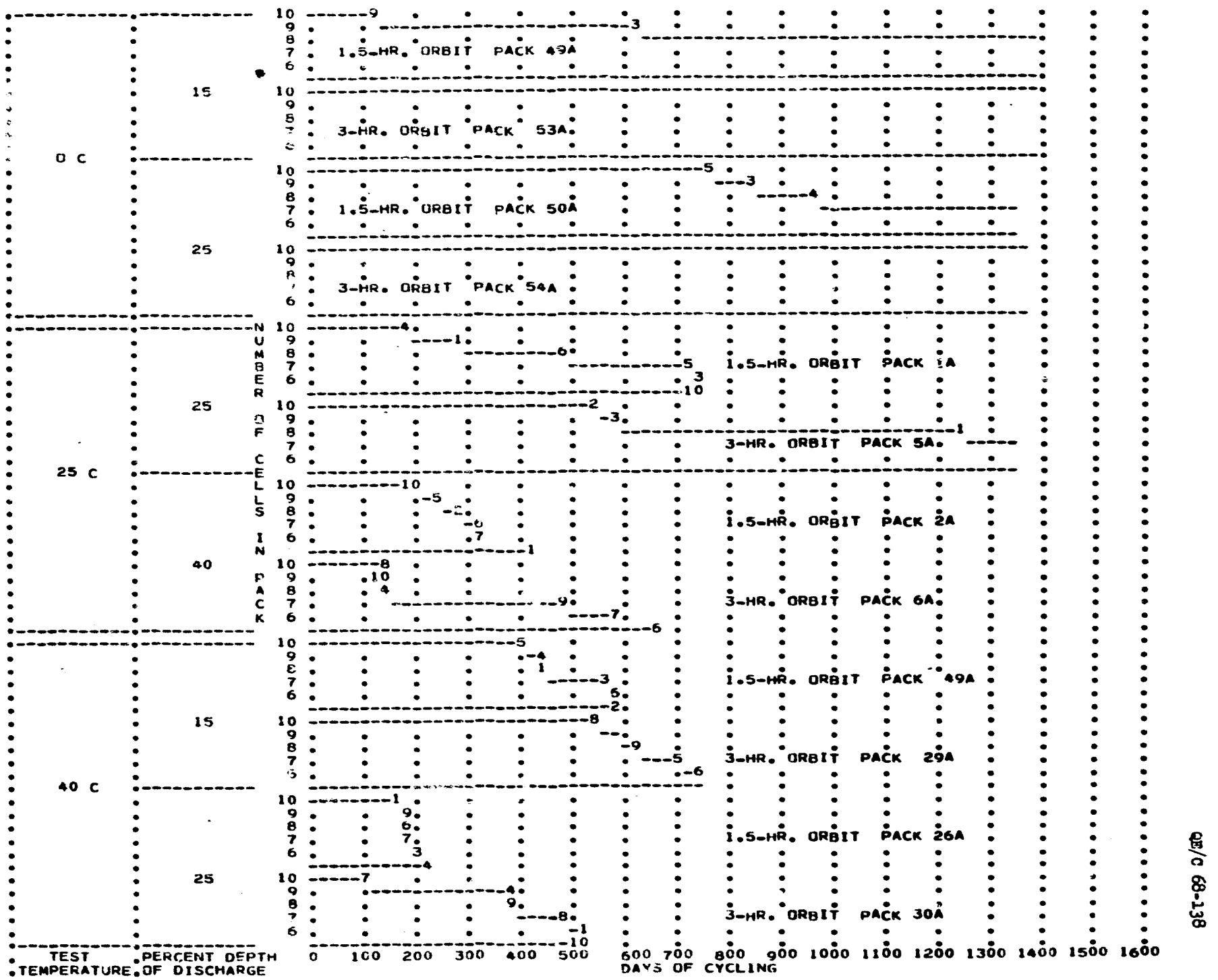



STATUS OF LIFE-CYCLING TEST CELL FAILURES AND DAYS OF CYCLING COMPLETED GULTON 20.0 A.H.

FIGURE 3(F)



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STATUS OF LIFE-CYCLING TEST CELL FAILURES AND DAYS OF CYCLING COMPLETED SONTONE 5.0 A.H.

FIGURE 3(G)

B. Cycling Performance of Nonfailing Cells; Voltage and Current Characteristics.

1. Figures 4(A) through 10(E) show variations of cycling voltage and percent of recharge for the packs that were cycling in 1967. All graphs containing data obtained prior to 1967 are contained in NAD Crane report QE/C 67-685. Complete data and graphs are available upon application via NASA Technical Officer. The application will include information on exactly what data is required; the use to which the data will be put; application details including orbital description, power supply schematics, etc., as appropriate; name and address of the activity that stands to benefit; name and telephone number of the responsible individual concerned and the affiliation with any Government agency as contractual arrangement. The points plotted on the graphs are the average voltage of the active cells at the middle of discharge (15 minutes), the end of discharge (30 minutes), and the end of charge; and the percent of recharge (the ratio of ampere-hours in to ampere-hours out). The number of active cells is listed across the top of the graph. These points are plotted at approximately 1-month intervals. If one or more of the symbols are missing for a given cycle plotted, this means that more than one point occupies the same location on the graph. Instead of printing both symbols, one on top of another, the symbol that is listed last in the "key" will be the only one to appear on the graph due to the methods used by the computer to make these graphs.

2. As shown in Figures 4(A) through 10(E), discharge voltages tend to drop slightly or remain the same over a period of 4 years. The drop is usually not more than 0.04 volt per active cell. The exceptions to this are immediately after a capacity check when there is an increase in the discharge voltage shown on the graph as a sharp rise; and when a cell is about to fail, the average voltage drops more rapidly. The least overall change is seen at 0° C. However, the Gulton 20 ah pack (Pack 91A) at 40° C, 25 percent depth of discharge and 3-hour orbit period, showed a fairly steady rise in end-of-discharge voltage from 0.9 volt per cell shortly after the change from 50° C to 40° C to 1.0 volt at the end of 10 months of cycling and remained there until the pack failed after almost 19 months of cycling. For a given temperature and cell type, the discharge voltage is generally from 0.02 to 0.08 volt per cell lower at the greater depths of discharge, that is, at the higher rate, as expected. For a given cell type, the discharge voltage tends to decrease by 0.0 to 0.1 volt per cell with increase in test temperature from 0° C to 40° C for each depth of discharge. The amount of decrease depends on the cell type. The orbit period seems to have little effect on the discharge characteristics of normally functioning cells (the 1.5-hour and 3-hour orbit periods both have 30-minute discharge periods).

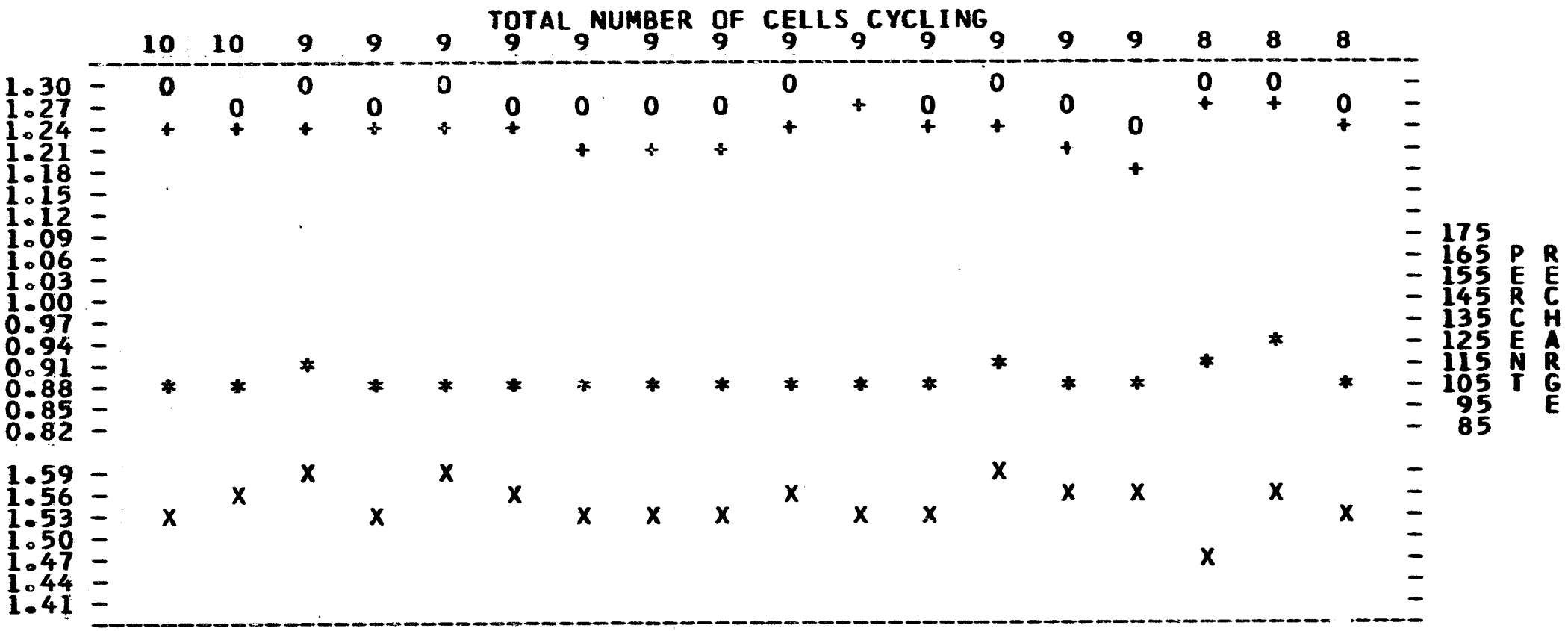
3. The percent of recharge and the end-of-charge voltage must be considered simultaneously since the amount by which the current is reduced during the charge portion of a given cycle is determined by the pack voltage. A tendency towards an increasing end-of-charge voltage will be reflected as a decrease in the percent of recharge if the specified voltage limit is reached. If the voltage limit, as shown in Table II, is not reached, the charge current remains constant at the specified rate throughout the charge period giving the specified percent of recharge.

a. When limiting occurs, the resulting percent of recharge may vary from one recorded cycle to the next if regular cycling has been interrupted by a capacity check, cell failure or equipment maintenance. The percent of recharge then may also stabilize at a new level if the voltage limit at which the control unit automatically converts from constant current to constant voltage operation is changed slightly (the tolerance is ± 0.03 volt per cell, average). Thus, if this voltage limiting point is increased, the percent of recharge will at least temporarily show an increase.

b. When pronounced long term changes in the percent of recharge and end-of-charge voltage occurred, they were almost always in the direction of lower percent of recharge and higher voltage although some of the packs did have an increase in the percent of recharge. On the average, packs operating at 0° C had an early percent of recharge of 107 percent and after 4 years it was 105 percent. While at 25° C, the early percent of recharge was 120 percent and after 4 years it was 118 percent. At 40° C, the early percent of recharge was 153 percent and after 4 years it was 146 percent. At all temperatures the percent of recharge is, on the average, below the specified percent of recharge indicating that the amount of recharge need not be as high as was originally set for the testing program.

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KEY: 0 – AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ – AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* – PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X – AVERAGE CELL VOLTAGE AT END OF CHARGE



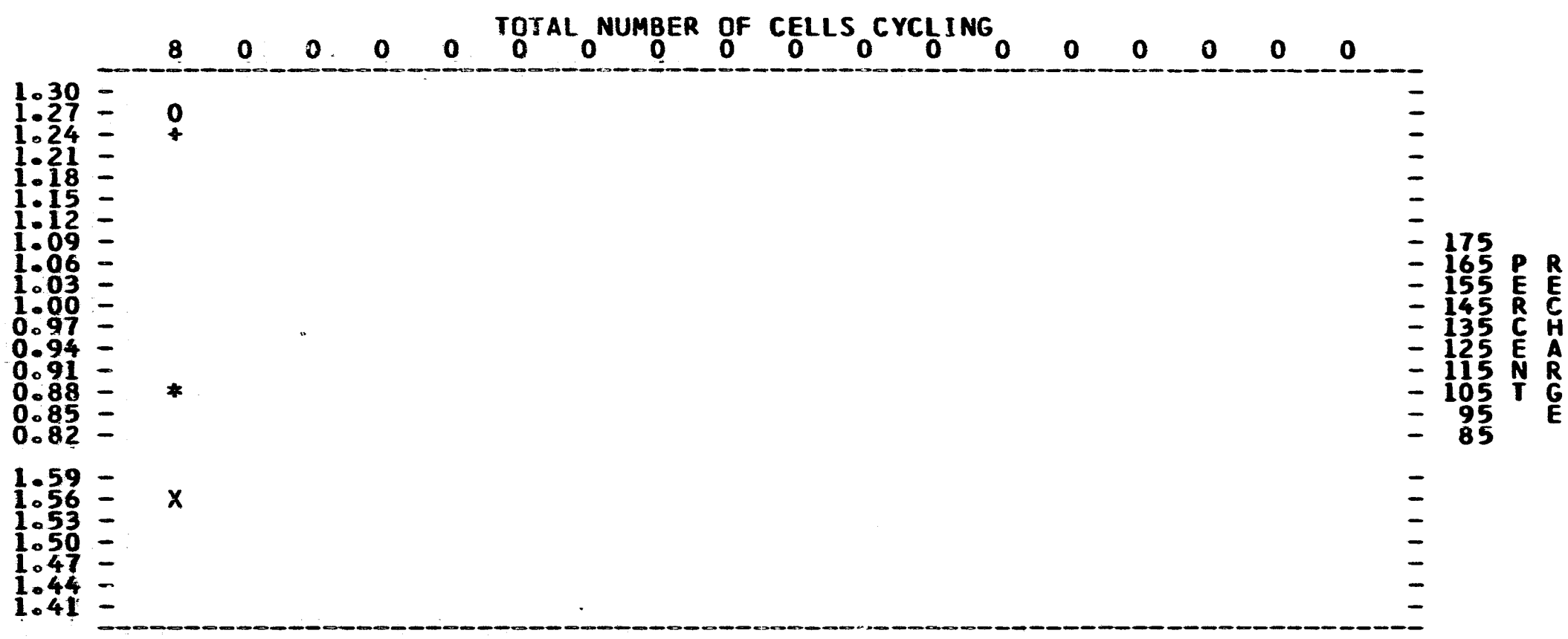

| POS. NO. | CYCLE FAILED | | |
|---|---|---|---|
| 06 | 14917 | PACK NUMBER | 063A |
| 04 | 20126 | TYPE OF CELLS | GE 3.00 AH |
| | | TEST TEMPERATURE | 00 DEGREES C. |
| | | ORBIT PERIOD | 01.5 HOURS |
| | | DEPTH OF DISCHARGE | 15 PERCENT |
| | | SPECIFIED CHARGE RATE | 0.52 AMP. |
| | | STATUS CELLS CYCLING | 8 |
| | | CYCLES COMPLETED | 22023 |

CAPACITY CHECK CYCLES
1546, 2944, 4100, 5607, 7057
8707, 8881, 9835,11282,13136
14377,15908,17641,19047,

FIGURE 4(A)

KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE

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| POS. NO. | CYCLE FAILED |
|---|---|
| 06 | 14917 |
| 04 | 20126 |

PACK NUMBER 063A
TYPE OF CELLS GE 3.00 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 15 PERCENT
SPECIFIED CHARGE RATE 0.52 AMP.

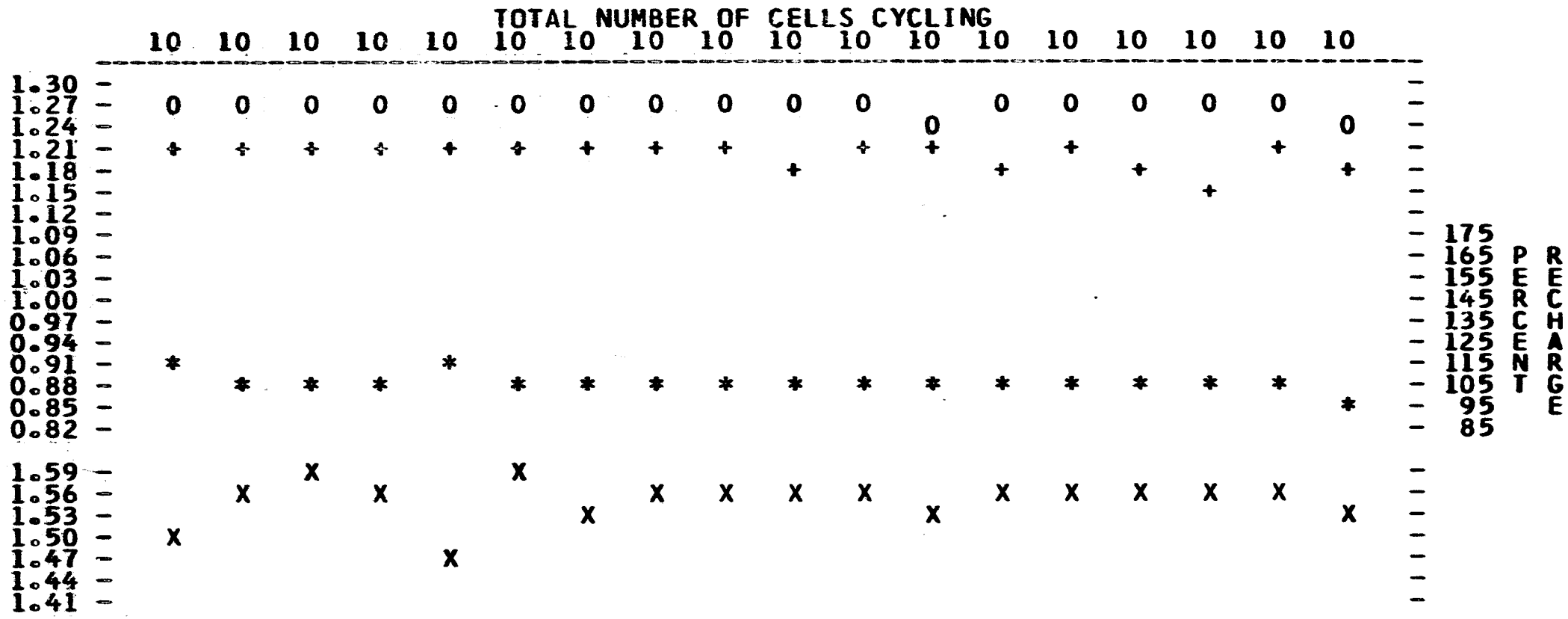
STATUS CELLS CYCLING 8
CYCLES COMPLETED 22023

CAPACITY CHECK CYCLES
1546, 2944, 4100, 5607, 7057
8707, 8881, 9835, 11282, 13136
14377, 15908, 17641, 19047,

FIGURE 4(A) (CONTD)

KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE

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POS. NO. CYCLE FAILED

PACK NUMBER 064A
TYPE OF CELLS GE 3.00 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 0.86 AMP.

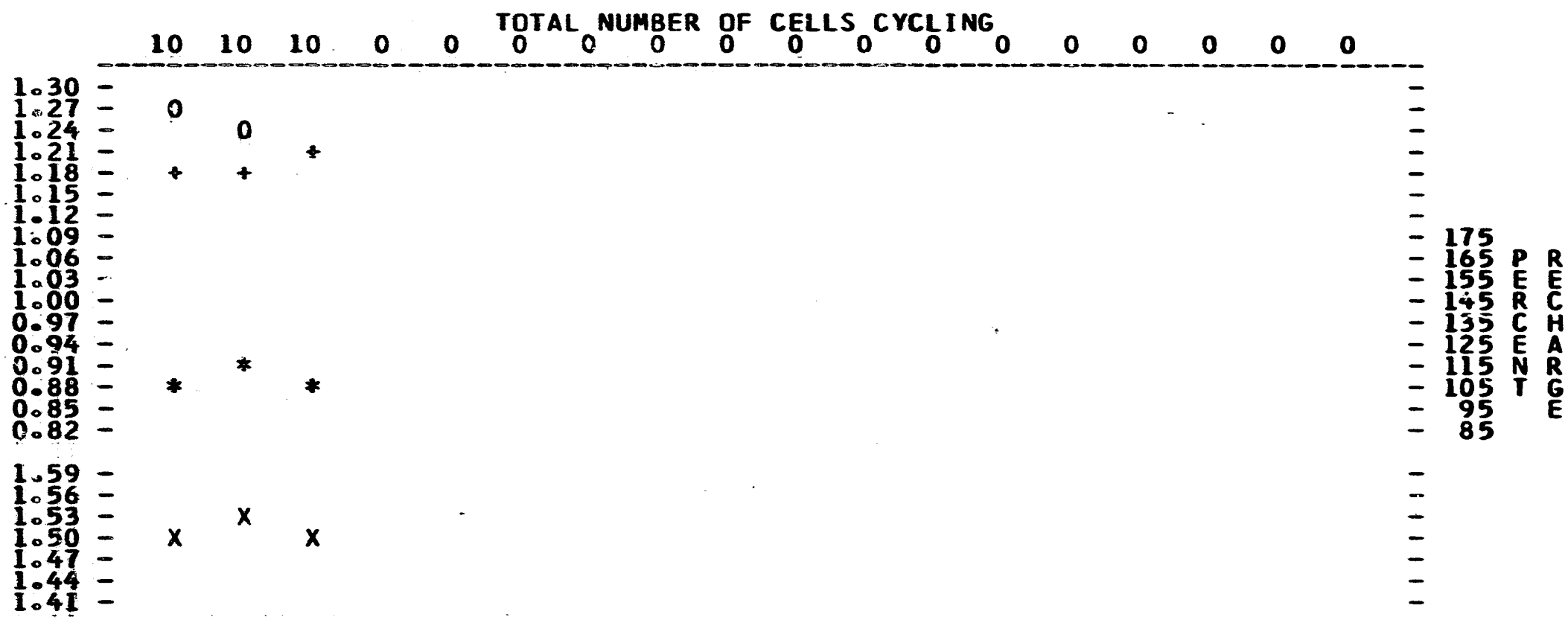
STATUS CELLS CYCLING 10
CYCLES COMPLETED 22525

CAPACITY CHECK CYCLES
144[illegible], 2841, 4045, 5472, 7012
8743, 10096, 11704, 13335, 14723
16342, 18069, 19555, 20741,

FIGURE 4(B)

KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE

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POS. NO. CYCLE FAILED

PACK NUMBER 064A
TYPE OF CELLS GE 3.00 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 0.86 AMP.

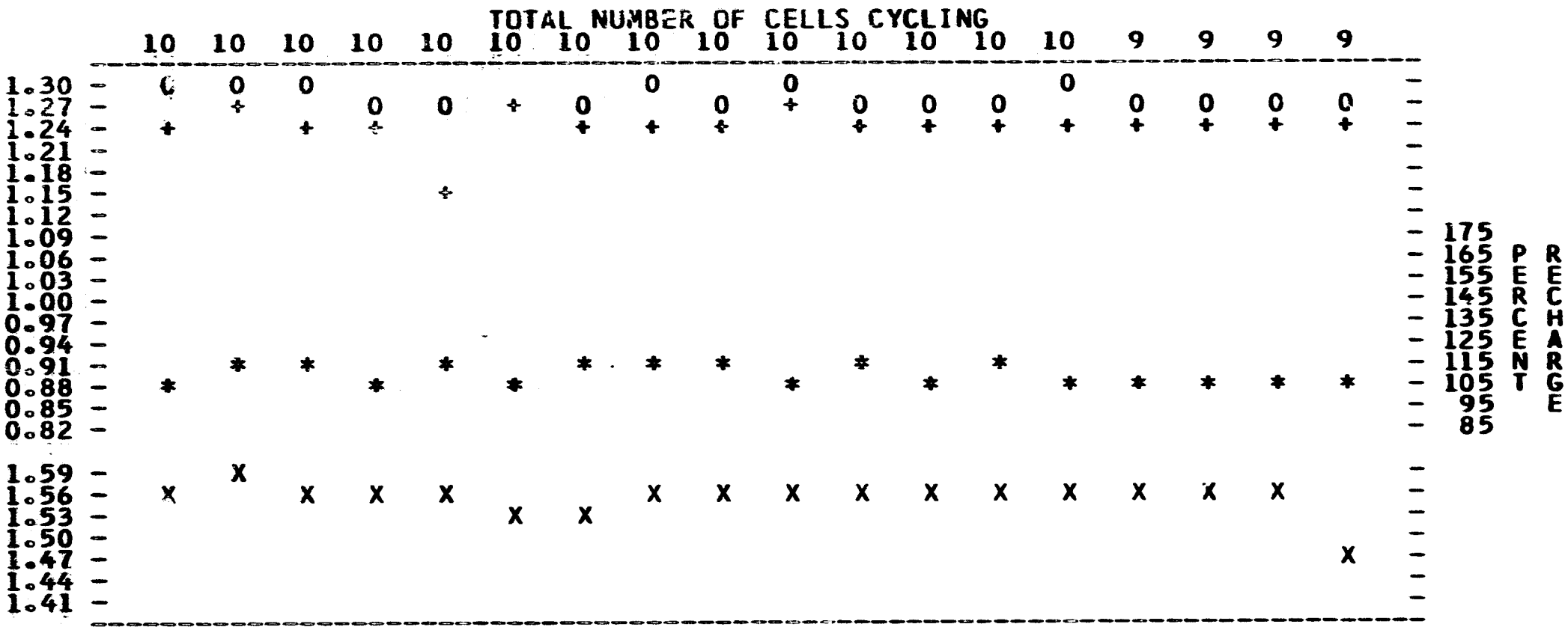
STATUS CELLS CYCLING 10
CYCLES COMPLETED 32525

CAPACITY CHECK CYCLES
1442, 2841, 4045, 5472, 7012
8743, 10096, 11704, 13335, 14723
16342, 18069, 19555, 20741,

FIGURE 4(B) (CONTD)

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KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE




POS. NO. 03 CYCLE FAILED 9980

PACK NUMBER 067A
TYPE OF CELLS GE 3.00 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 03.0 HOURS
DEPTH OF DISCHARGE 15 PERCENT
SPECIFIED CHARGE RATE 0.21 AMP.

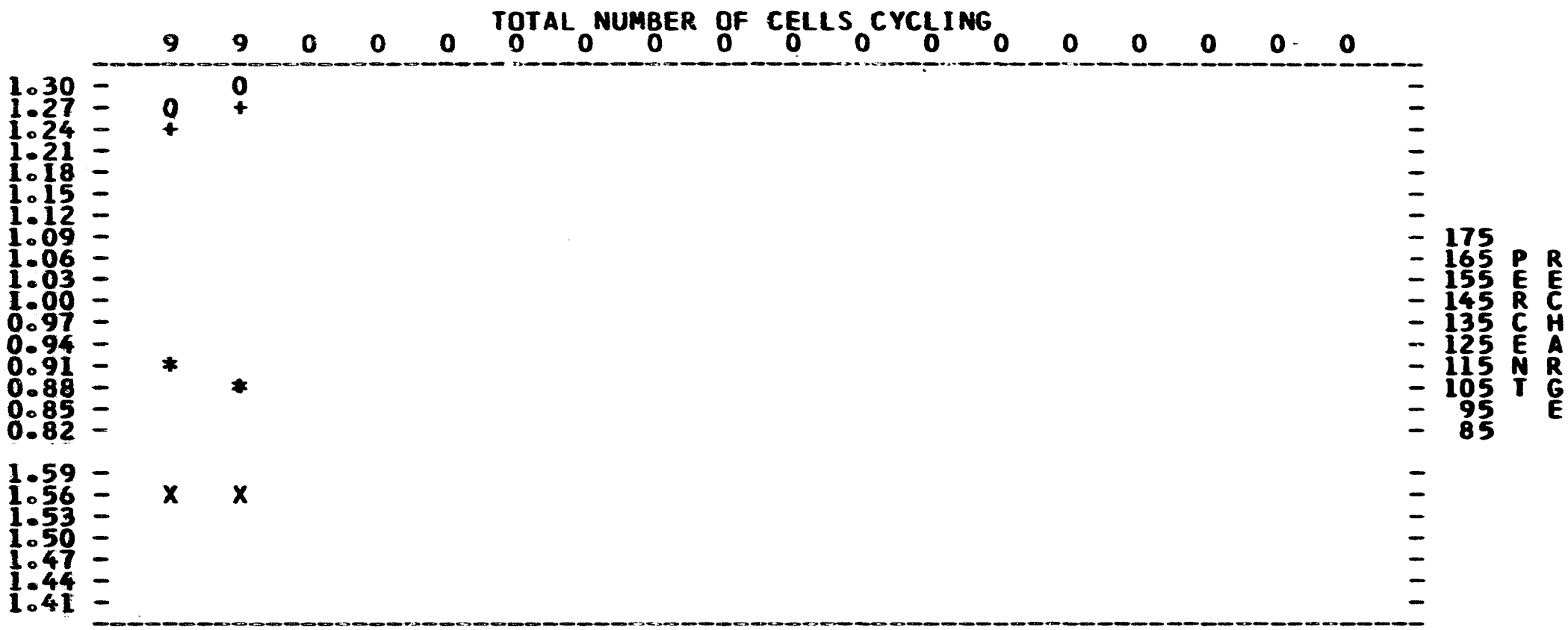
STATUS CELLS CYCLING 9
CYCLES COMPLETED 11068

CAPACITY CHECK CYCLES
719, 1374, 2015, 2762, 3504
4271, 4918, 5702, 6508, 7247
8204, 8979, 9682,10230,

FIGURE 4(C)

KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE

QE/C 68-138



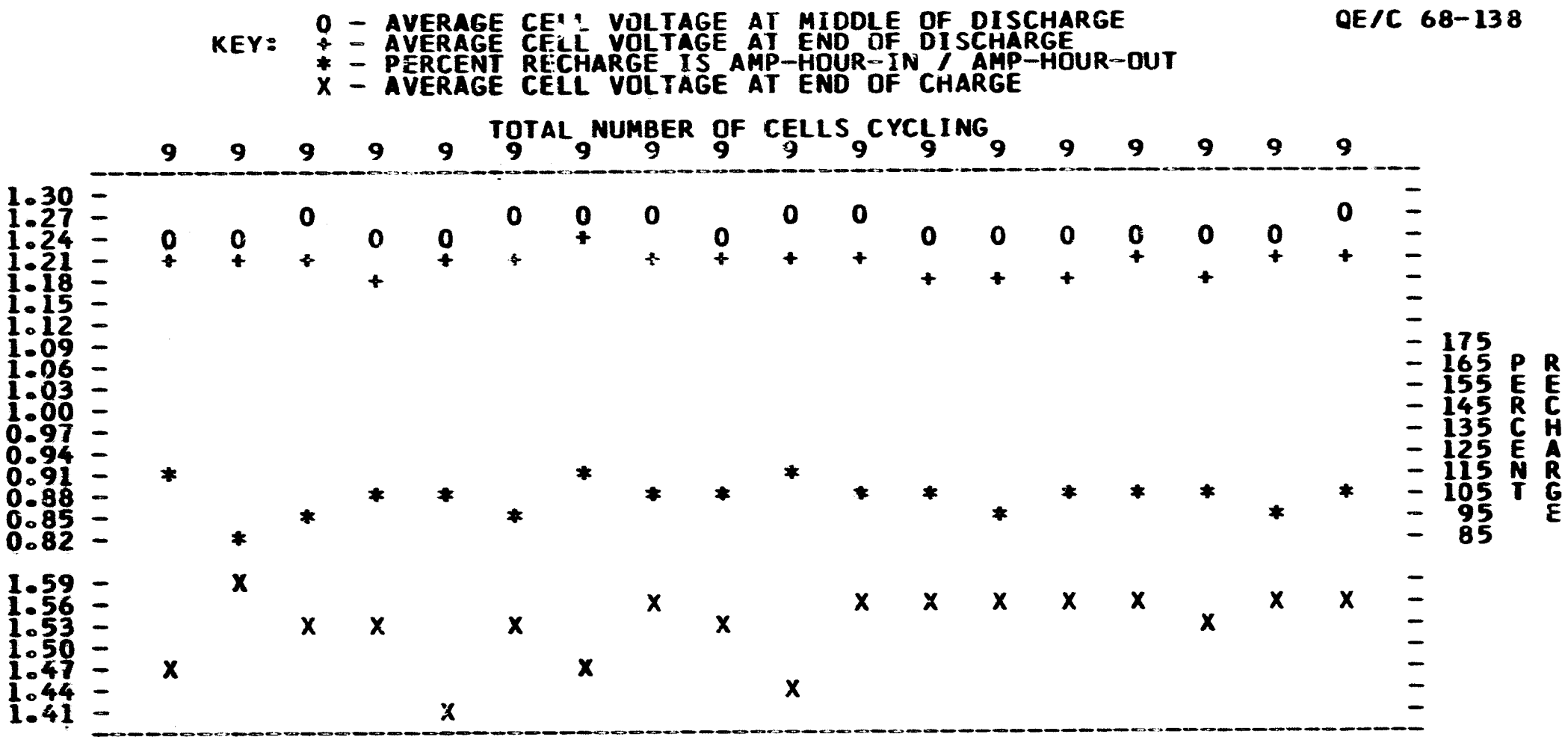

POS. NO. 03 CYCLE FAILED 9980

PACK NUMBER 067A
TYPE OF CELLS GE 3.00 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 03.0 HOURS
DEPTH OF DISCHARGE 15 PERCENT
SPECIFIED CHARGE RATE 0.21 AMP

STATUS CELLS CYCLING 9
CYCLES COMPLETED 11068

CAPACITY CHECK CYCLES
719, 1374, 2015, 2762, 3504
4271, 4918, 5702, 6508, 7247
8204, 8979, 9682,10230,

FIGURE 4(C) (CONTD)



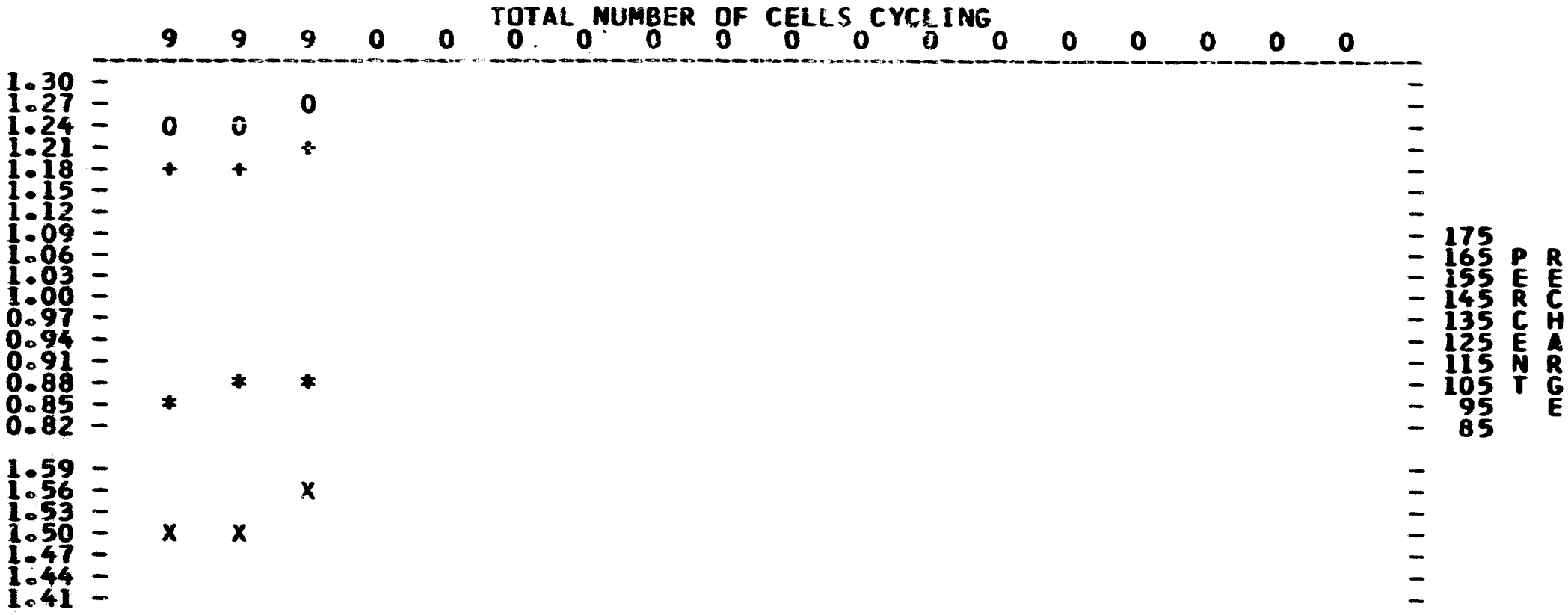

| | | | |
|---|---|---|---|
| POS. NO. | CYCLE FAILED | PACK NUMBER | 068A |
| 09 | 7054 | TYPE OF CELLS | GE 3.00 AH |
| | | TEST TEMPERATURE | 00 DEGREES C. |
| | | ORBIT PERIOD | 03.0 HOURS |
| | | DEPTH OF DISCHARGE | 25 PERCENT |
| | | SPECIFIED CHARGE RATE | 0.34 AMP. |
| | | STATUS CELLS CYCLING | 9 |
| | | CYCLES COMPLETED | 11280 |

CAPACITY CHECK CYCLES
715, 1431, 2050, 2804, 3508
4364, 4956, 5802, 6608, 7166
8103, 9162, 9866,10457,

FIGURE 4(D)

KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE

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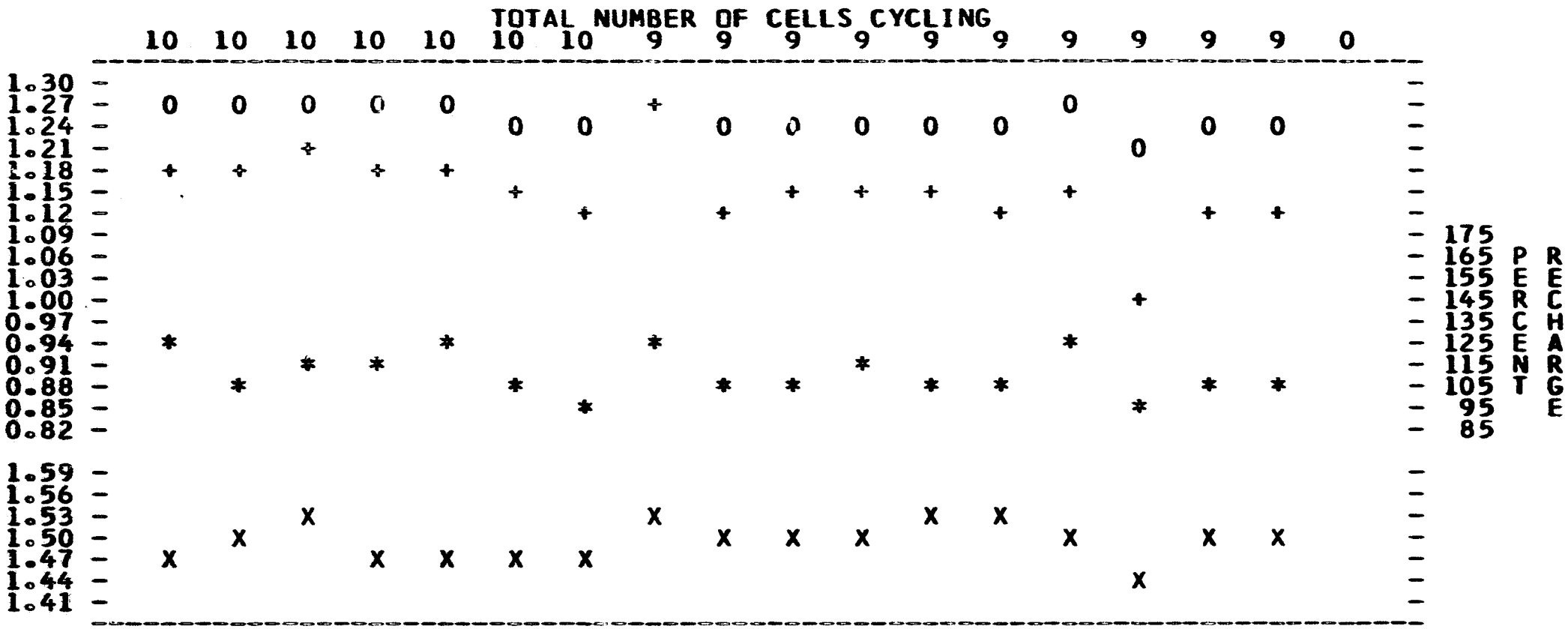

| | | |
|---|---|---|
| POS. NO. 09 | CYCLE FAILED 7054 | PACK NUMBER 068A |
| | | TYPE OF CELLS GE 3.00 AH |
| | | TEST TEMPERATURE 00 DEGREES C. |
| | | ORBIT PERIOD 03.0 HOURS |
| | | DEPTH OF DISCHARGE 25 PERCENT |
| | | SPECIFIED CHARGE RATE 0.34 AMP. |
| | | STATUS CELLS CYCLING 9 |
| | | CYCLES COMPLETED 11280 |

CAPACITY CHECK CYCLES
715, 1431, 2050, 2804, 3508
4364, 4956, 5802, 6608, 7166
8103, 9162, 9866,10457,

FIGURE 4(D) (CONTD)

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KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE




| POS. NO. | CYCLE FAILED | | |
|---|---|---|---|
| 01 | 8572 | | |

PACK NUMBER 019A
TYPE OF CELLS GE 3.00 AH
TEST TEMPERATURE 25 DEGREES C.
ORBIT PERIOD 03.0 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 0.38 AMP.

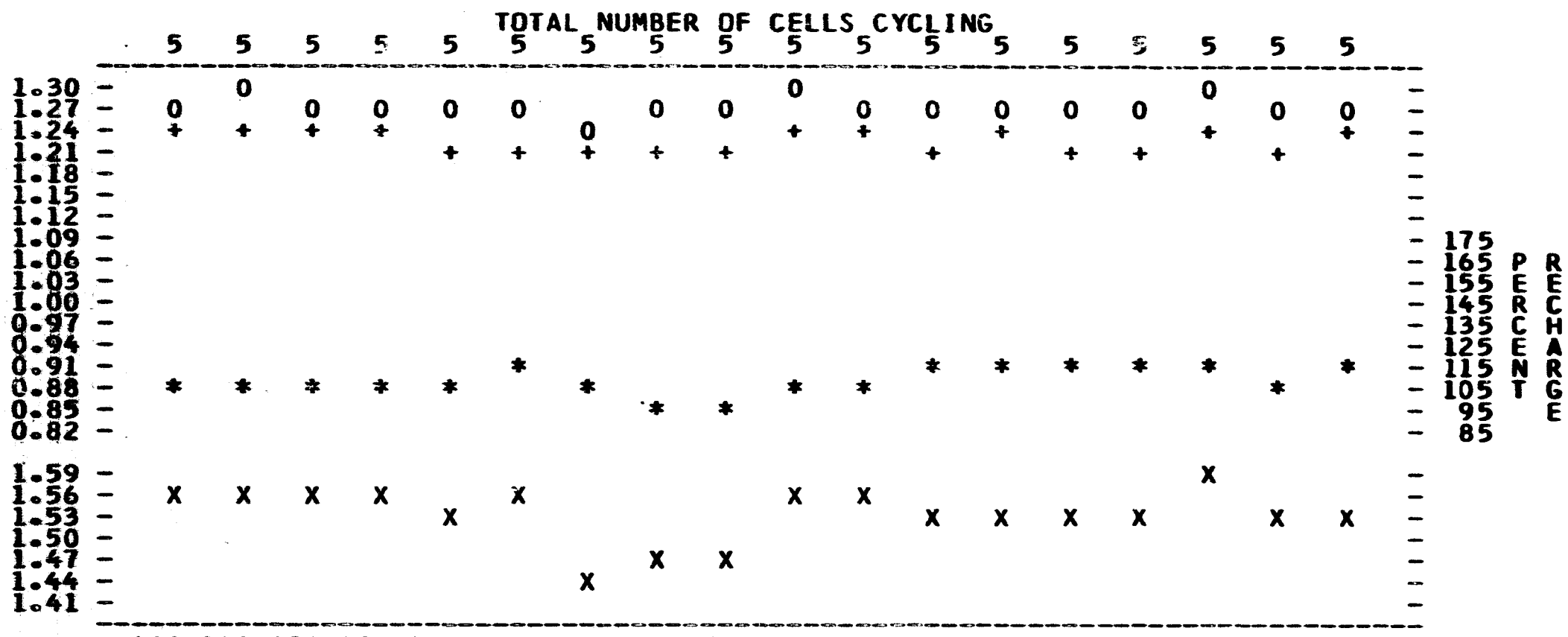
STATUS CELLS CYCLING 9
CYCLES COMPLETED 10340

CAPACITY CHECK CYCLES
674, 1381, 2008, 2722, 3432
4241, 4822, 5607, 6429, 7085
7977, 8590, 9074, 9668,

FIGURE 4(E)

KEY: 0 – AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ – AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* – PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X – AVERAGE CELL VOLTAGE AT END OF CHARGE

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POS. NO. CYCLE FAILED

PACK NUMBER 110A
TYPE OF CELLS GE 12.00 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 15 PERCENT
SPECIFIED CHARGE RATE 2.07 AMP.

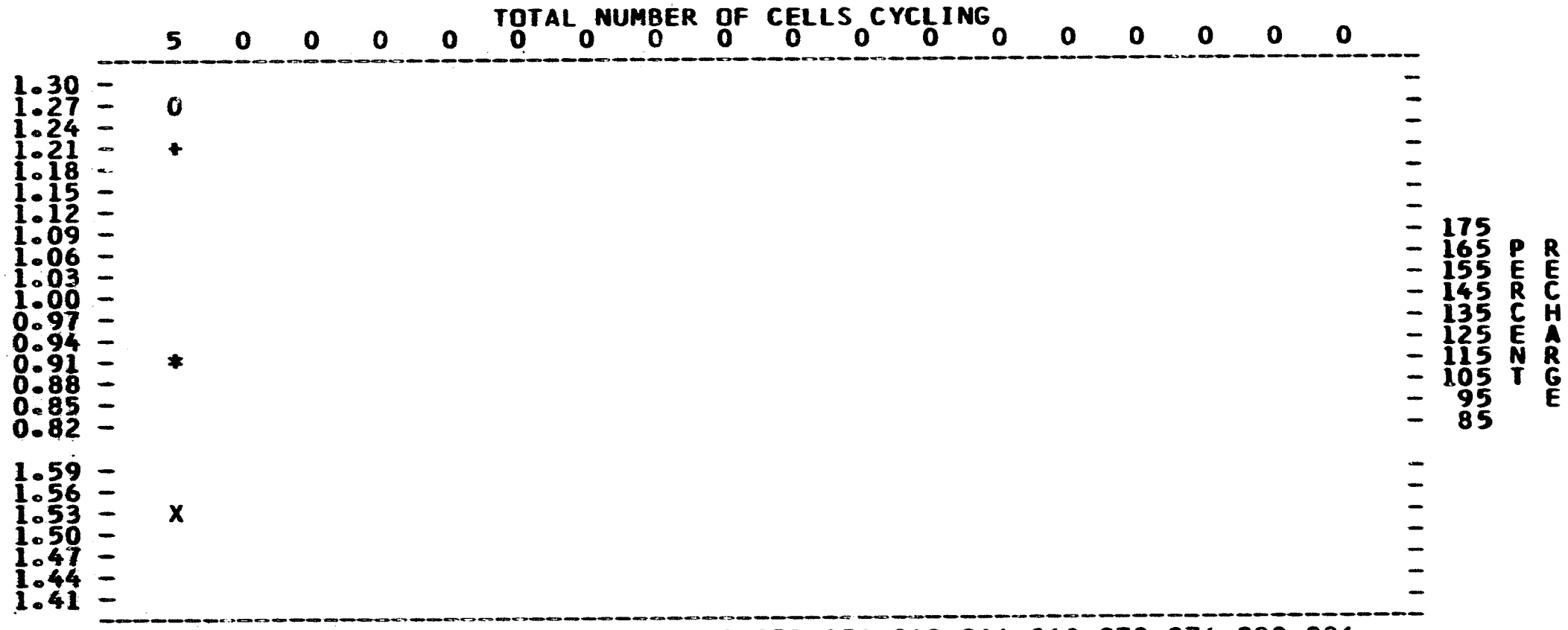
STATUS CELLS CYCLING 5
CYCLES COMPLETED 21957

CAPACITY CHECK CYCLES
1440, 2898, 4410, 5805, 7189
8619, 9777, 11495, 13095, 14556
16288, 17727, 19021, 20204,

FIGURE 5(A)

KEY: 0 – AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ – AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* – PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X – AVERAGE CELL VOLTAGE AT END OF CHARGE

QE/C 68-138




POS. NO. CYCLE FAILED

PACK NUMBER 110A
TYPE OF CELLS GE 12.00 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 15 PERCENT
SPECIFIED CHARGE RATE 2.07 AMP.

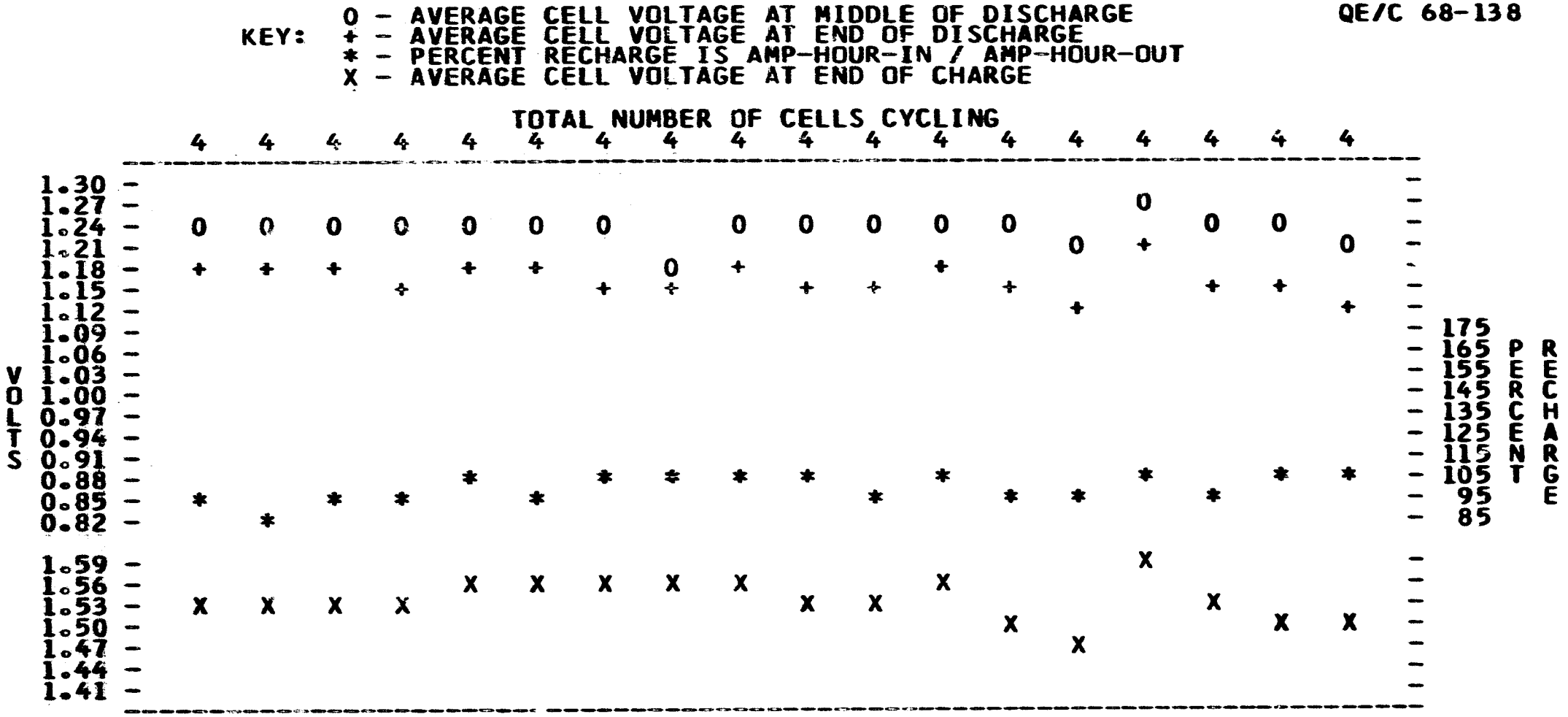
STATUS CELLS CYCLING 5
CYCLES COMPLETED 21957

CAPACITY CHECK CYCLES
1440, 2898, 4410, 5805, 7189
8619, 9777,11495,13095,14556
16288,17727,19021,20204,

FIGURE 5(A) (CONTD)

KEY: 0 – AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ – AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* – PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X – AVERAGE CELL VOLTAGE AT END OF CHARGE

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POS. NO. 03 CYCLE FAILED 13218

PACK NUMBER 124A
TYPE OF CELLS GE 12.00 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 3.45 AMP.

STATUS CELLS CYCLING 4
CYCLES COMPLETED 21547

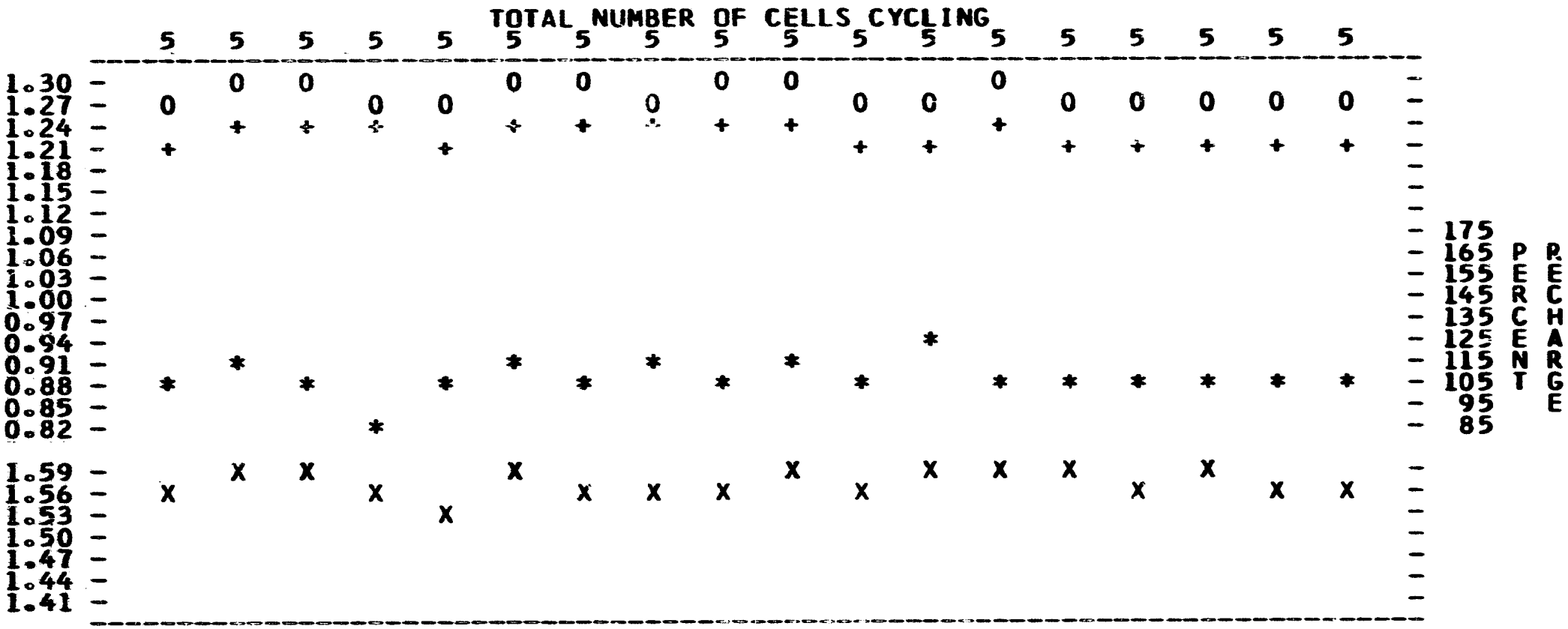
CAPACITY CHECK CYCLES
1481, 2976, 4301, 5520, 6956
8468, 9544, 11262, 12862, 14182
15915, 17354, 18723, 19907,

CYCLE 3037: POS.5 FAILED; PUT BACK IN PACK ON CYCLE 4375 AFTER REGAINING NORMAL CAPACITY DURING FAILURE TEST.

FIGURE 5(B)

QE/C 68-138

KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE




POS. NO. CYCLE FAILED

PACK NUMBER 111A
TYPE OF CELLS GE 12.00 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 03.0 HOURS
DEPTH OF DISCHARGE 15 PERCENT
SPECIFIED CHARGE RATE 0.83 AMP.

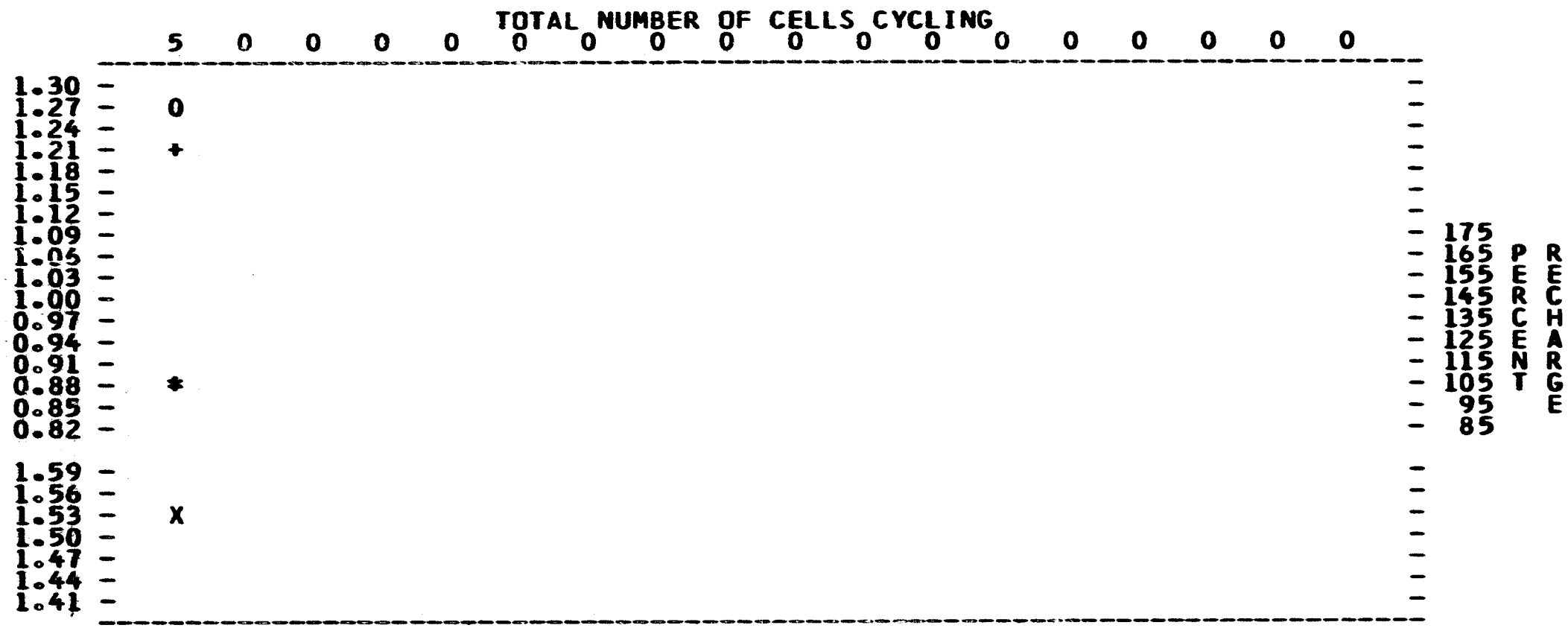
STATUS CELLS CYCLING 5
CYCLES COMPLETED 10835

CAPACITY CHECK CYCLES
696, 1533, 2179, 2871, 3558
4302, 4884, 5750, 6469, 7188
8100, 8789, 9509,10198,

FIGURE 5(C)

KEY: 0 – AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ – AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* – PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X – AVERAGE CELL VOLTAGE AT END OF CHARGE

QE/C 68-138

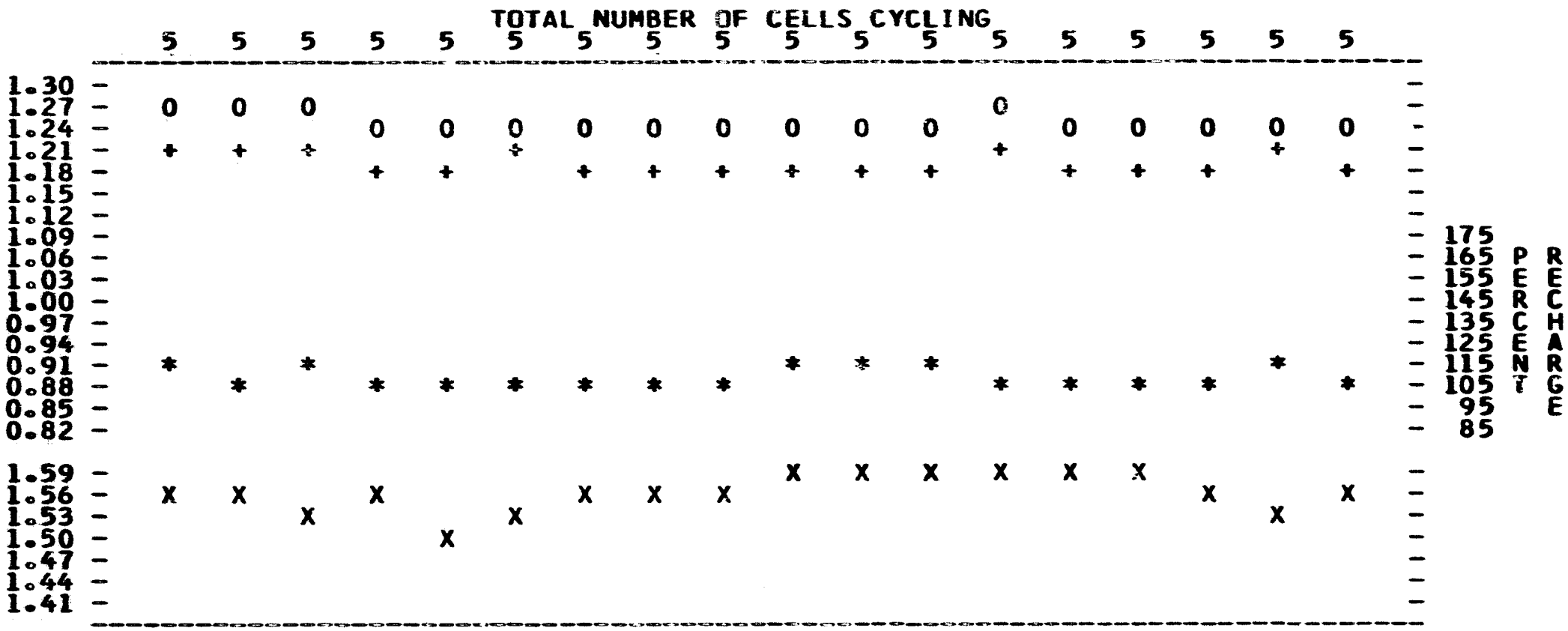



| POS. NO. | CYCLE FAILED | | | CAPACITY CHECK CYCLES |
|---|---|---|---|---|
| | | PACK NUMBER | 111A | 696, 1533, 2179, 2871, 3558 |
| | | TYPE OF CELLS | GE 12.00 AH | 4302, 4884, 5750, 6469, 7188 |
| | | TEST TEMPERATURE | 00 DEGREES C. | 8100, 8789, 9509,10198, |
| | | ORBIT PERIOD | 03.0 HOURS | |
| | | DEPTH OF DISCHARGE | 15 PERCENT | |
| | | SPECIFIED CHARGE RATE | 0.83 AMP. | |
| | | STATUS CELLS CYCLING | 5 | |
| | | CYCLES COMPLETED | 10835 | |

FIGURE 5(C) (CONTD)

KEY: 0 – AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ – AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* – PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X – AVERAGE CELL VOLTAGE AT END OF CHARGE

QE/C 68-138




POS. NO. CYCLE FAILED

PACK NUMBER 125A
TYPE OF CELLS GE 12.00 AH
TEST TEMPERATURE 10 DEGREES C.
ORBIT PERIOD 03.0 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 1.38 AMP.

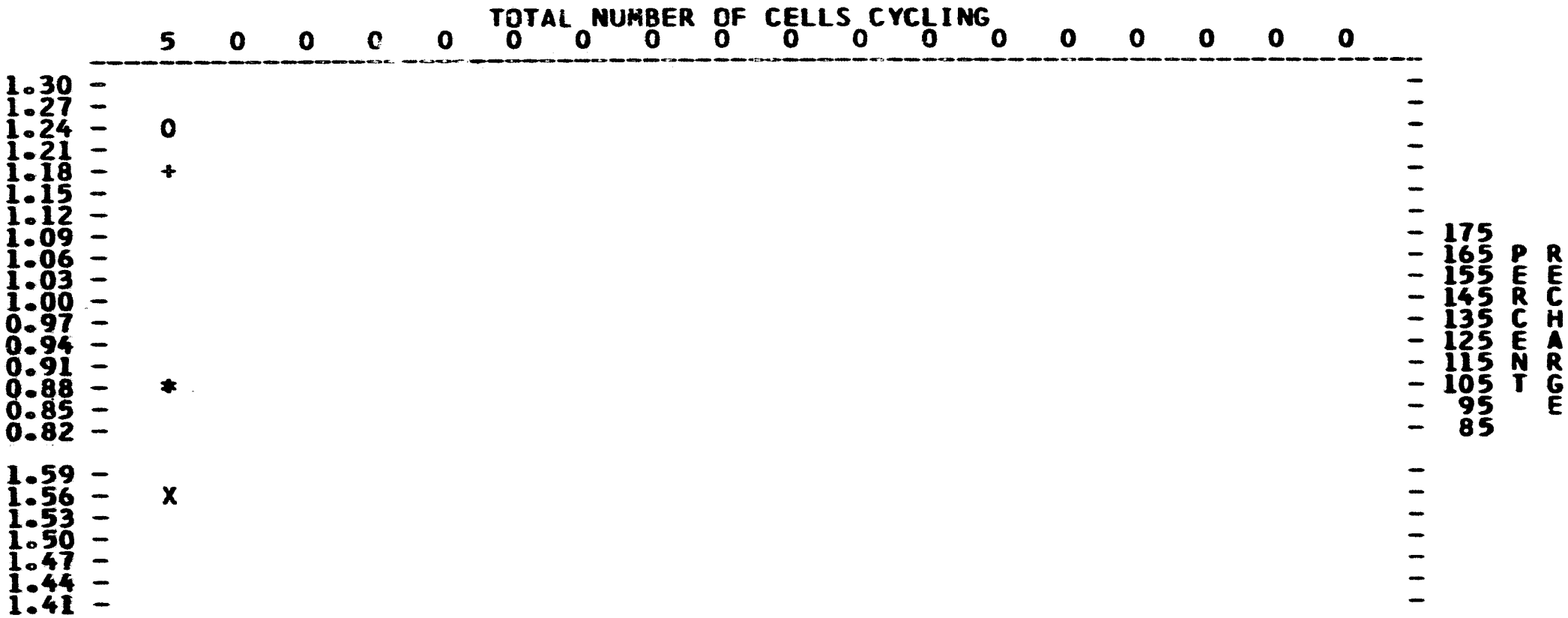
STATUS CELLS CYCLING 5
CYCLES COMPLETED 10907

CAPACITY CHECK CYCLES
695, 1533, 2178, 2870, 3532
4343, 4877, 5743, 6443, 7193
8172, 8861, 9581,10270,

FIGURE 5(D)

KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
÷ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE

QE/C 68-138




POS. NO. CYCLE FAILED

PACK NUMBER 125A
TYPE OF CELLS GE 12.00 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 03.0 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 1.38 AMP.

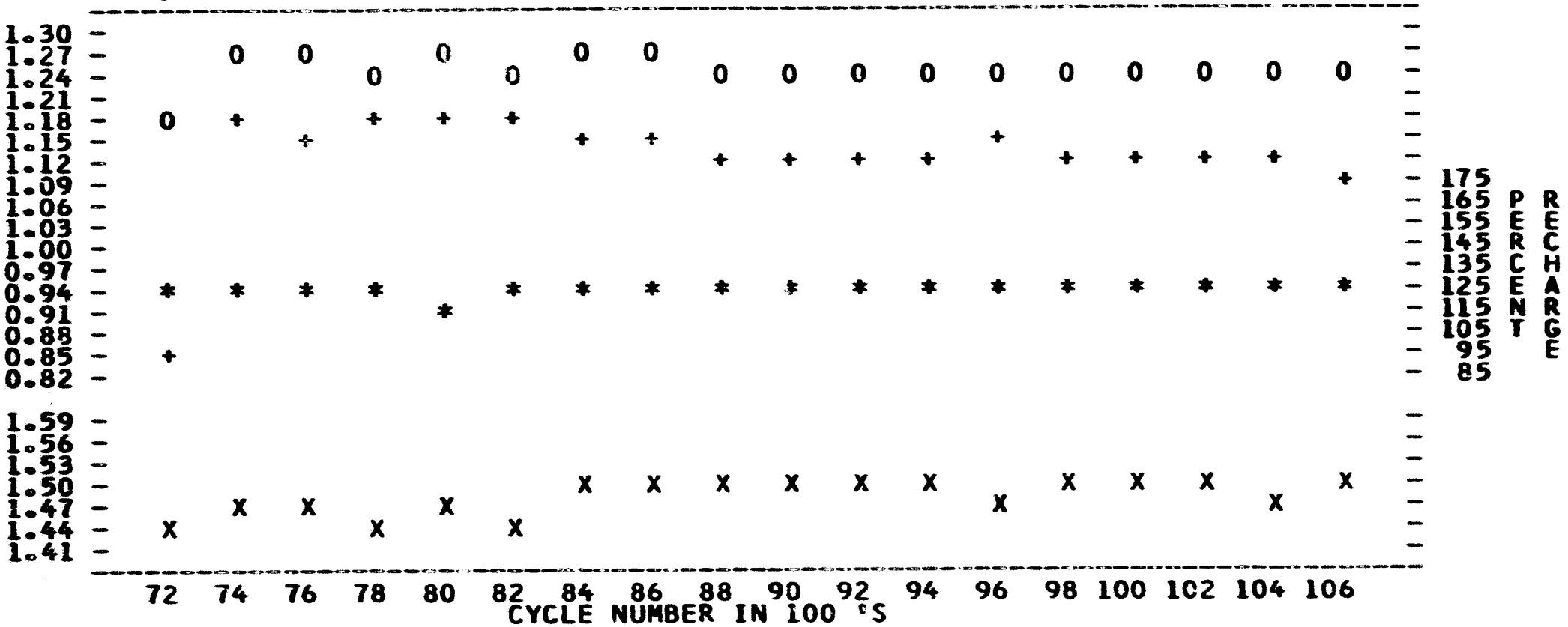
STATUS CELLS CYCLING 5
CYCLES COMPLETED 10907

CAPACITY CHECK CYCLES
695, 1533, 2178, 2870, 3532
4343, 4877, 5743, 6443, 7193
8172, 8851, 9581,10270,

FIGURE 5(D) (CONTD)

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KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE




POS. NO. CYCLE FAILED

PACK NUMBER 083A
TYPE OF CELLS GE 12.00 AH
TEST TEMPERATURE 25 DEGREES C.
ORBIT PERIOD 03.0 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 1.50 AMP.

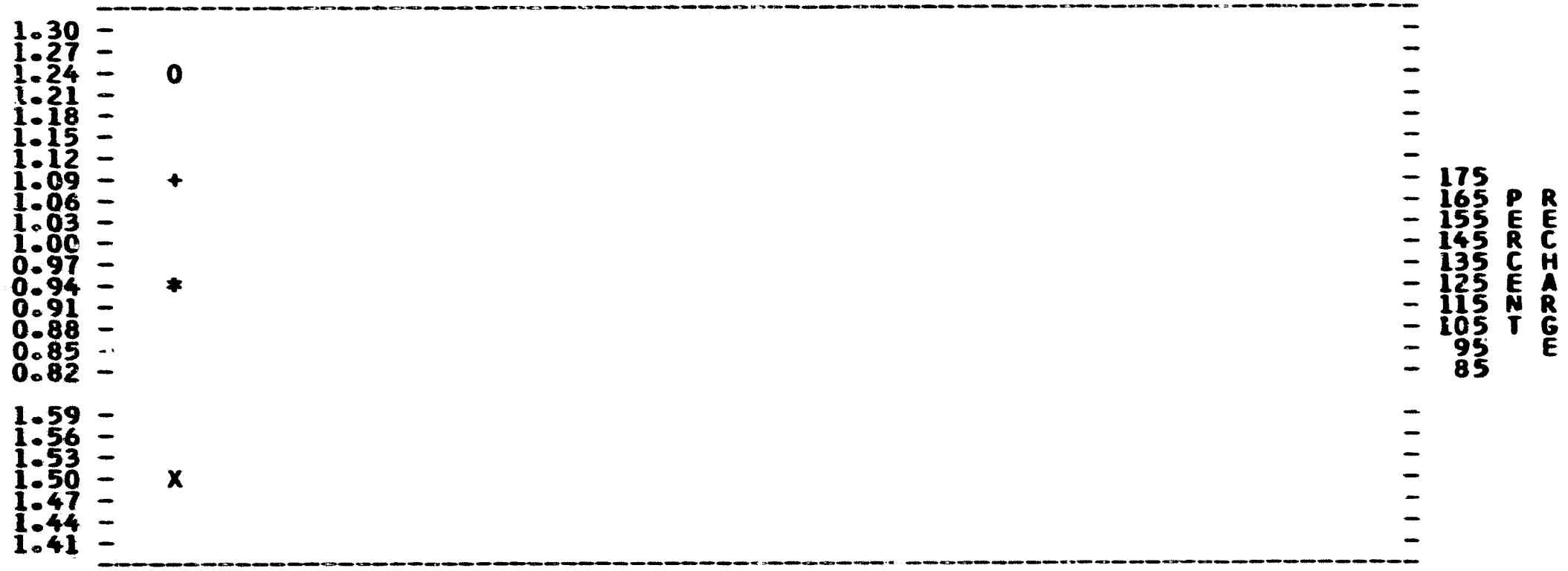
STATUS CELLS CYCLING 5
CYCLES COMPLETED 10955

CAPACITY CHECK CYCLES
693, 1362, 2155, 2816, 3496
4362, 4923, 5740, 6502, 7185
8143, 8491, 9542,10134,

FIGURE 5(E)

KEY: O - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
. - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE

QE/C 68-138



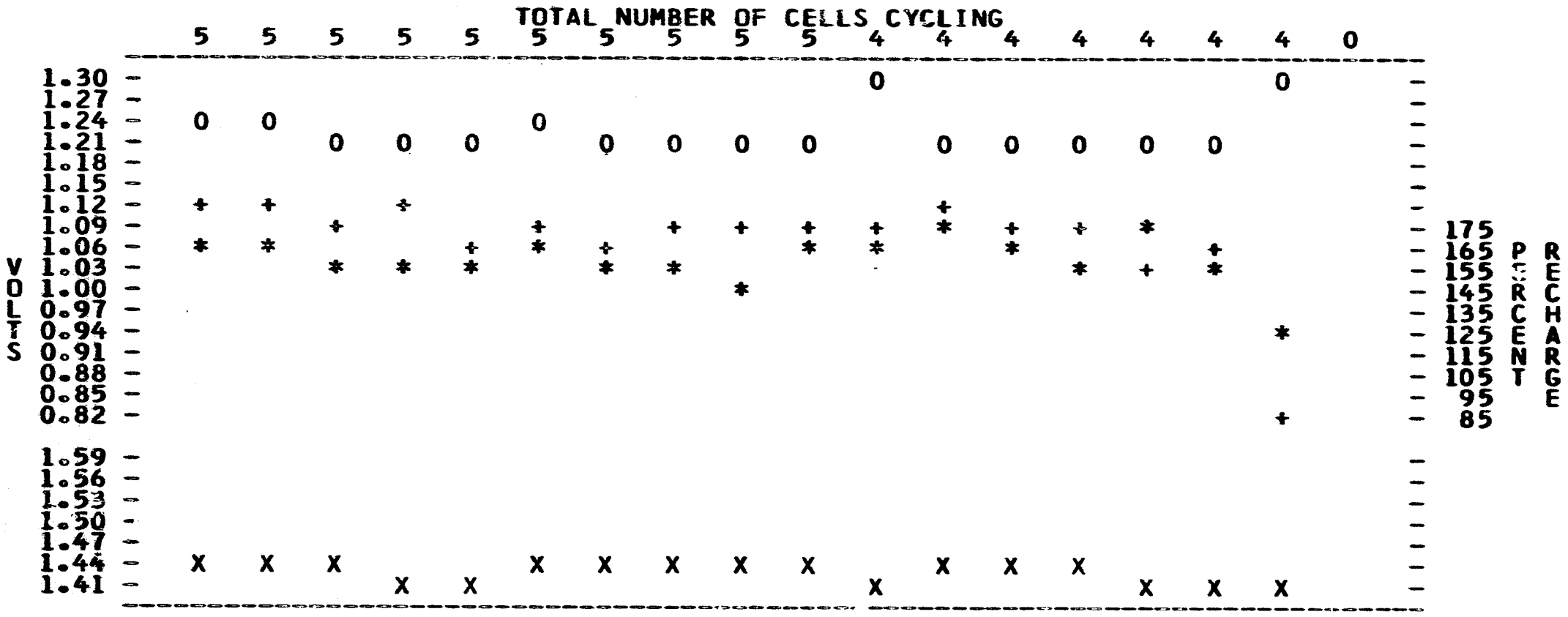

| | | | |
|---|---|---|---|
| POS. NO. | CYCLE FAILED | PACK NUMBER | 083A |
| | | TYPE OF CELLS | GE 12.00 AH |
| | | TEST TEMPERATURE | 25 DEGREES C. |
| | | ORBIT PERIOD | 03.0 HOURS |
| | | DEPTH OF DISCHARGE | 25 PERCENT |
| | | SPECIFIED CHARGE RATE | 1.50 AMP. |
| | | STATUS | CELLS CYCLING 5 |
| | | | CYCLES COMPLETED 10955 |

CAPACITY CHECK CYCLES
693, 1362, 2155, 2814, 3496
4362, 4923, 5740, 6502, 7185
8143, 8491, 9542,10134,

FIGURE 5(E) (CONTD)

KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP--HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE

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| POS. NO. | CYCLE FAILED |
|---|---|
| 03 | 8988 |
| 05 | 10575 |

PACK NUMBER 086A
TYPE OF CELLS GE 12.00 AH
TEST TEMPERATURE 40 DEGREES C.
ORBIT PERIOD 03.0 HOURS
DEPTH OF DISCHARGE 15 PERCENT
SPECIFIED CHARGE RATE 1.15 AMP.

STATUS CELLS CYCLING 3
CYCLES COMPLETED 10579

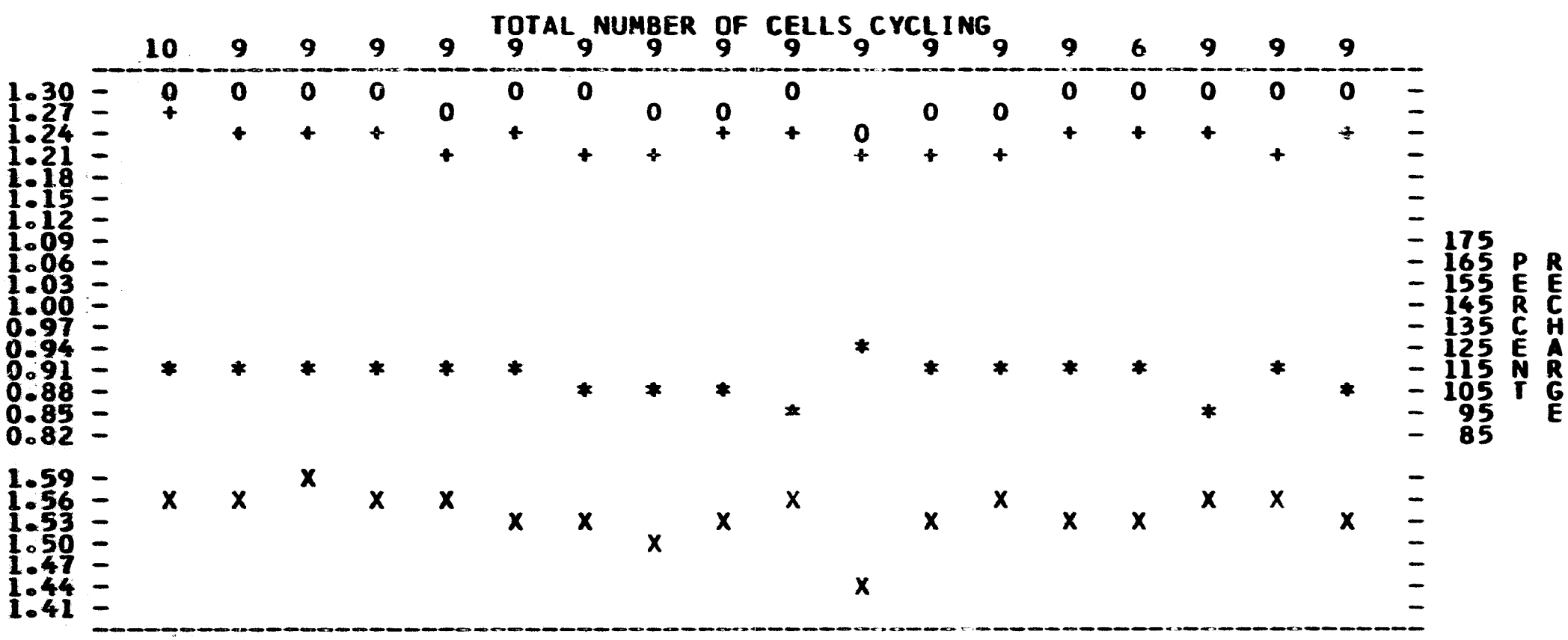
CAPACITY CHECK CYCLES
682, 1519, 2213, 2971, 3670
4372, 4823, 5654, 6419, 6909
7735, 8547, 9092, 9701,

CYCLE 205: CHANGED TO 40 DEGREES CENTIGRADE.
CYCLE 365: VOLTAGE LIMIT RAISED TO 1.45 VOLTS PER CELL.

FIGURE 5(F)

KEY: 0 – AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ – AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* – PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X – AVERAGE CELL VOLTAGE AT END OF CHARGE

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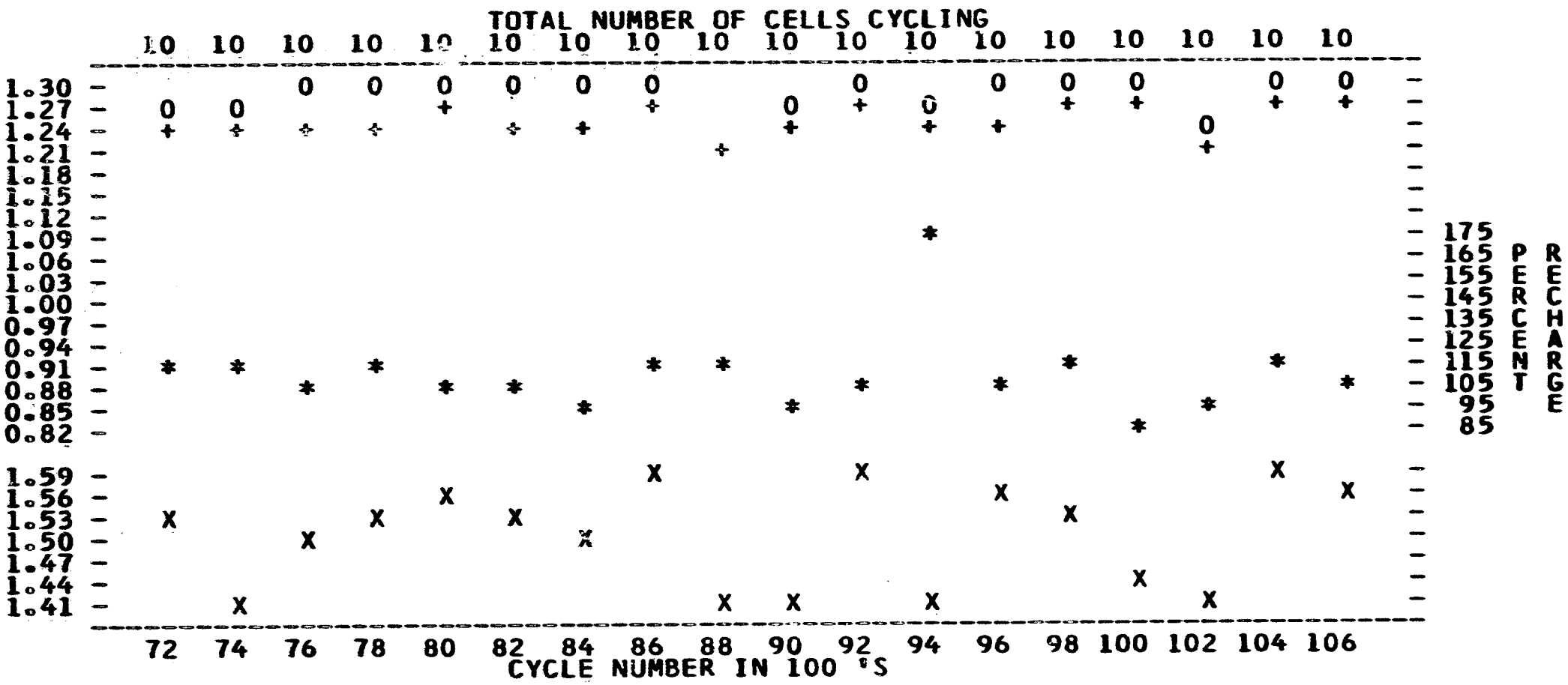

| | | |
|---|---|---|
| POS. NO. 10 | CYCLE FAILED 14737 | PACK NUMBER 051A |
| | | TYPE OF CELLS GOULD 3.50 AH |
| | | TEST TEMPERATURE 00 DEGREES C. |
| | | ORBIT PERIOD 01.5 HOURS |
| | | DEPTH OF DISCHARGE 15 PERCENT |
| | | SPECIFIED CHARGE RATE 0.60 AMP. |
| | | STATUS CELLS CYCLING 9 |
| | | CYCLES COMPLETED 21464 |

CAPACITY CHECK CYCLES
1546, 2944, 4165, 5565, 7074
8724, 8898, 9852, 11299, 13153
14347, 16067, 17800, 19206,

FIGURE 6(A)

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KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE




POS. NO. CYCLE FAILED

PACK NUMBER 055A
TYPE OF CELLS GOULD 3.50 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 03.0 HOURS
DEPTH OF DISCHARGE 15 PERCENT
SPECIFIED CHARGE RATE 0.24 AMP.

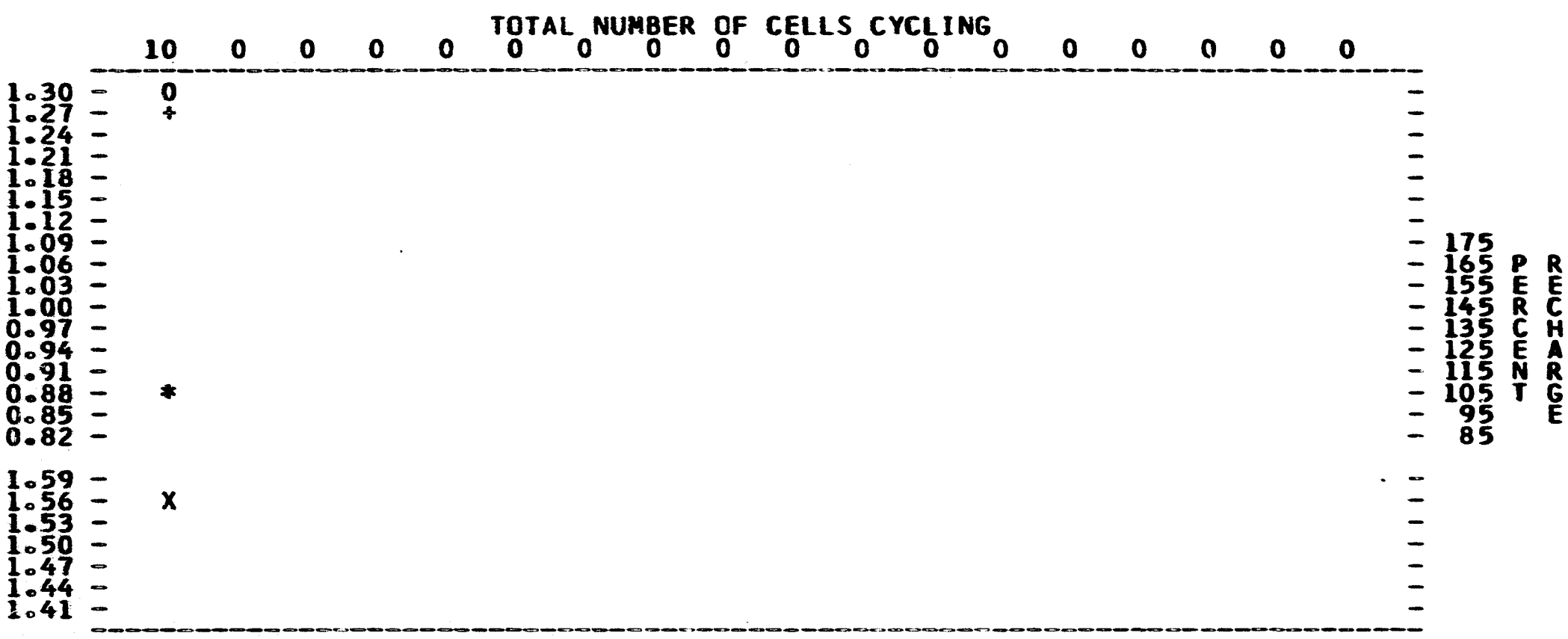
STATUS CELLS CYCLING 10
CYCLES COMPLETED 11072

CAPACITY CHECK CYCLES
719, 1374, 2015, 2762, 3504
4301, 4949, 5754, 6560, 7298
8255, 8980, 9683,10275,

FIGURE 6(B)

KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE

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POS. NO. CYCLE FAILED

PACK NUMBER 055A
TYPE OF CELLS GOULD 3.50 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 03.0 HOURS
DEPTH OF DISCHARGE 15 PERCENT
SPECIFIED CHARGE RATE 0.24 AMP.

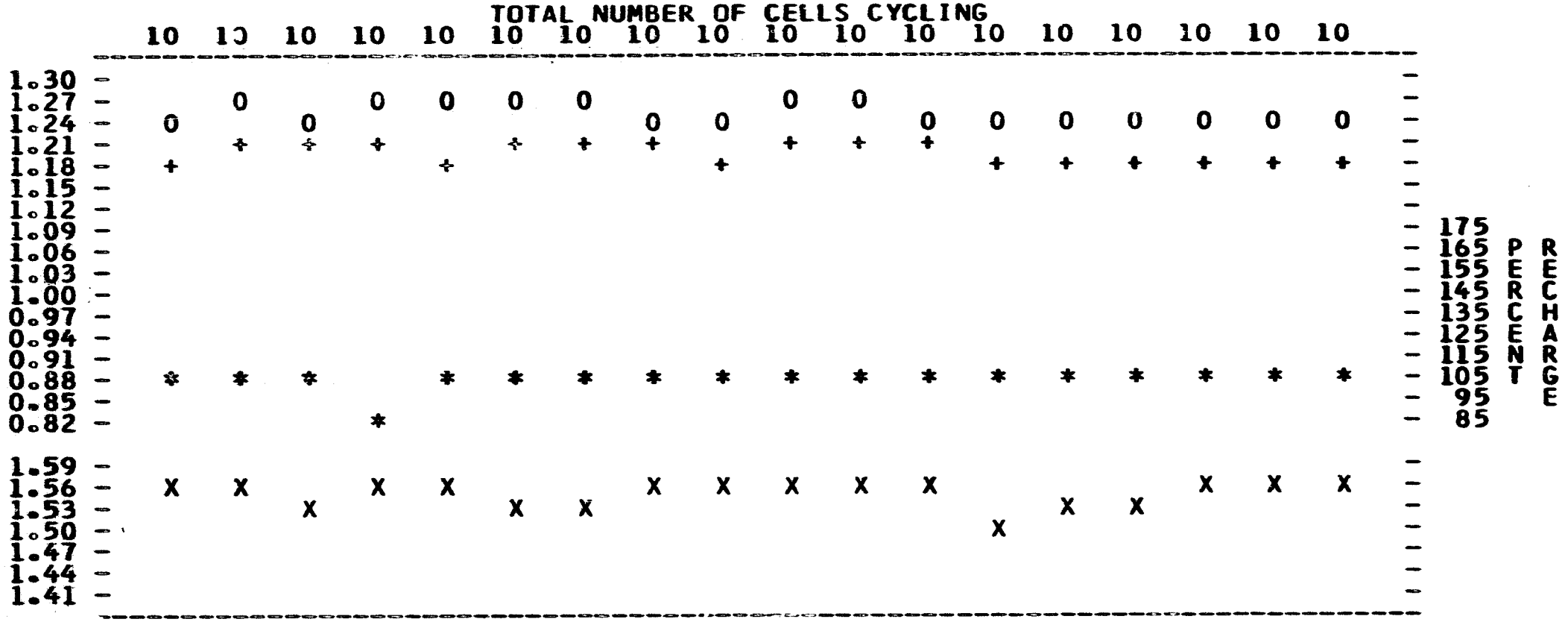
STATUS CELLS CYCLING 10
CYCLES COMPLETED 11072

CAPACITY CHECK CYCLES
719, 1374, 2015, 2762, 3504
4301, 4949, 5754, 6560, 7298
8255, 8980, 9683, 10275,

FIGURE 6(B) (CONTD)

KEY: 0 – AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ – AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* – PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X – AVERAGE CELL VOLTAGE AT END OF CHARGE

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POS. NO. CYCLE FAILED

PACK NUMBER 056A
TYPE OF CELLS GOULD 3.50 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 03.0 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 0.40 AMP.

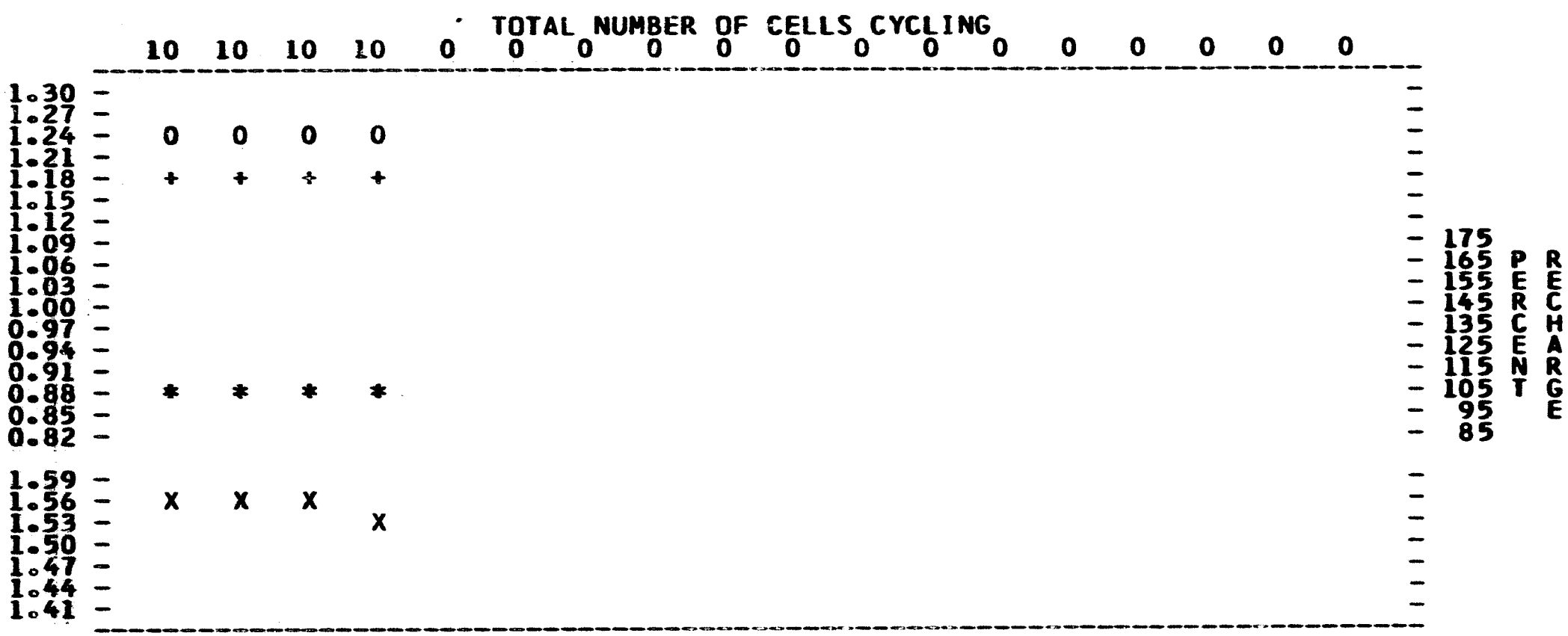
STATUS CELLS CYCLING 10
CYCLES COMPLETED 11423

CAPACITY CHECK CYCLES
715, 1415, 2034, 2788, 3475
4335, 4927, 5765, 6572, 7311
8245, 9304,10007,10585,

FIGURE 6(C)

QE/C 68-138

KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE




POS. NO. CYCLE FAILED

PACK NUMBER 056A
TYPE OF CELLS GOULD 3.50 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 03.0 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 0.40 AMP.

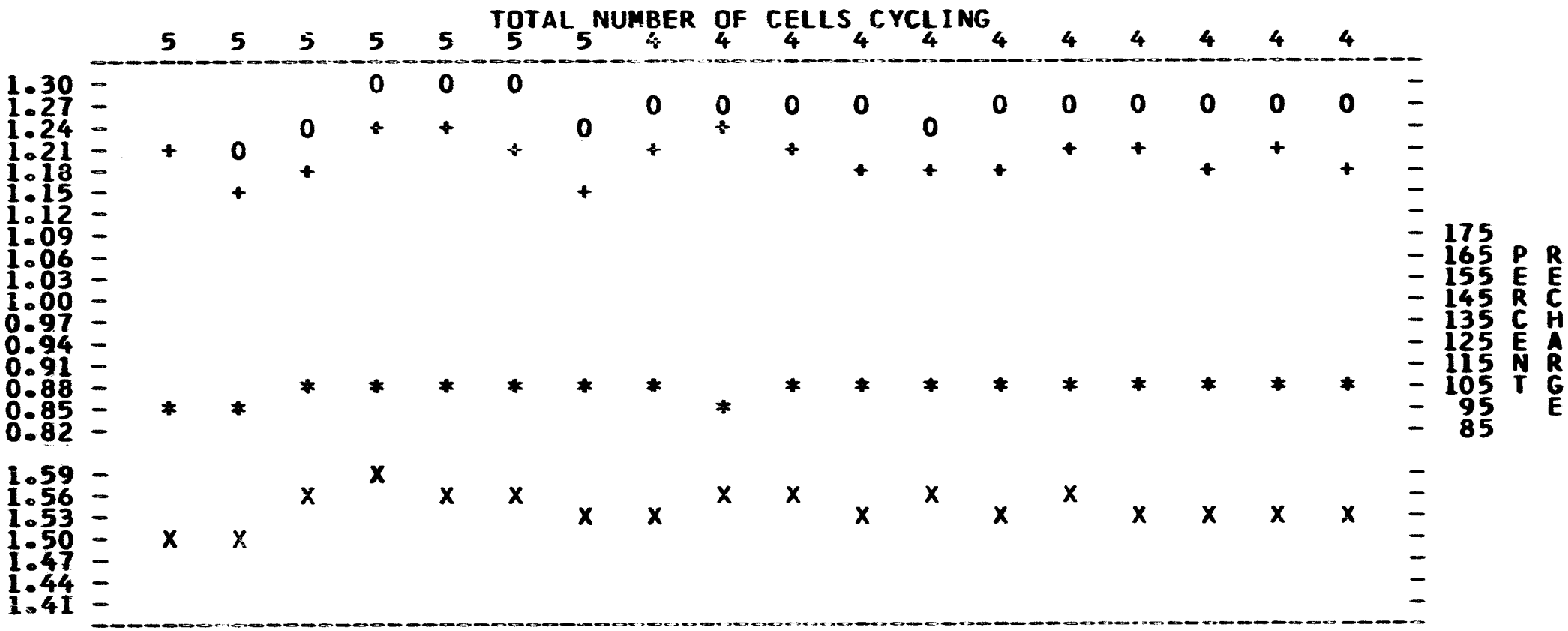
STATUS CELLS CYCLING 10
CYCLES COMPLETED 11423

CAPACITY CHECK CYCLES
715, 1415, 2034, 2788, 3475
4335, 4927, 5765, 6572, 7311
8245, 9304,10007,10585,

FIGURE 6(C) (CONTD)

KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE

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POS. NO. 05

CYCLE FAILED 17040

PACK NUMBER 084A
TYPE OF CELLS GOULD 20.00 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 15 PERCENT
SPECIFIED CHARGE RATE 3.45 AMP.

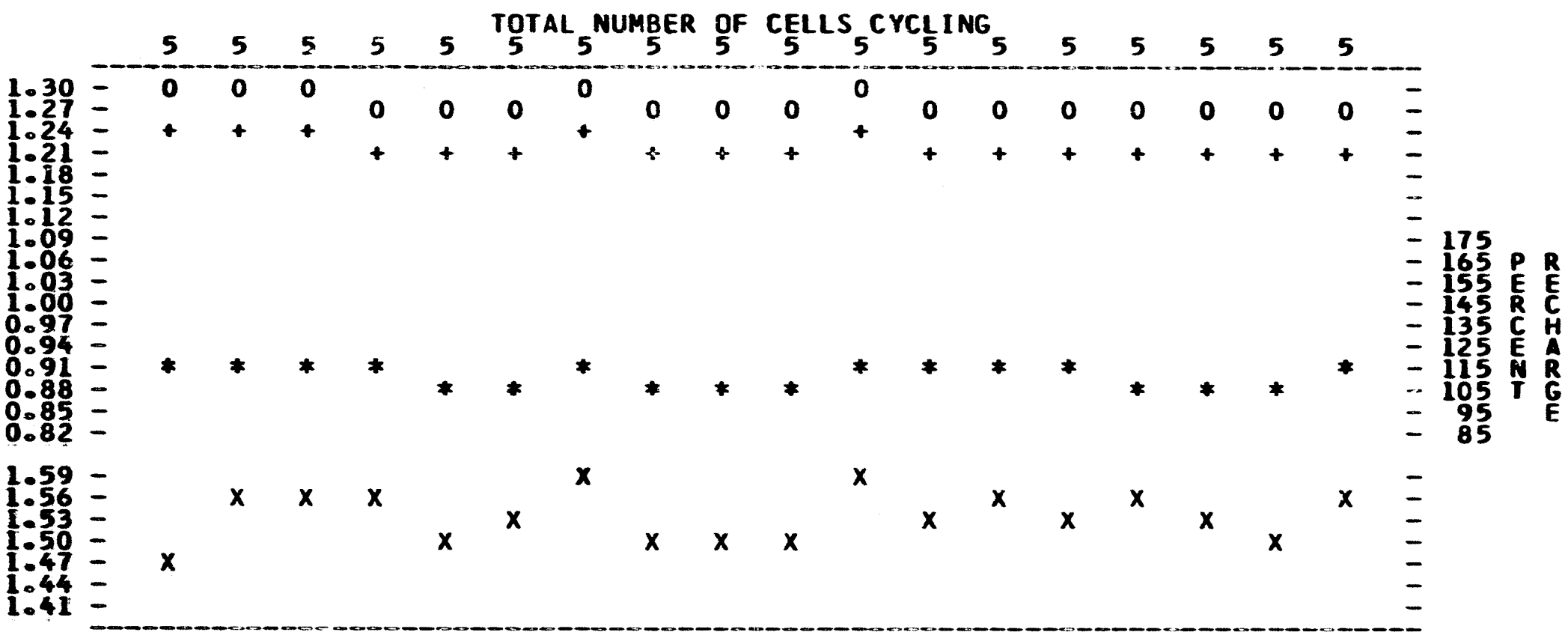
STATUS CELLS CYCLING 4
CYCLES COMPLETED 21576

CAPACITY CHECK CYCLES
1471, 3133, 4378, 5848, 7163
8453, 9612,11329,12917,14385
16128,17263,19040,20448,

FIGURE 7(A)

KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE

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POS. NO. CYCLE FAILED

PACK NUMBER 080A
TYPE OF CELLS GOULD 20.00 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 03.0 HOURS
DEPTH OF DISCHARGE 15 PERCENT
SPECIFIED CHARGE RATE 1.38 AMP.

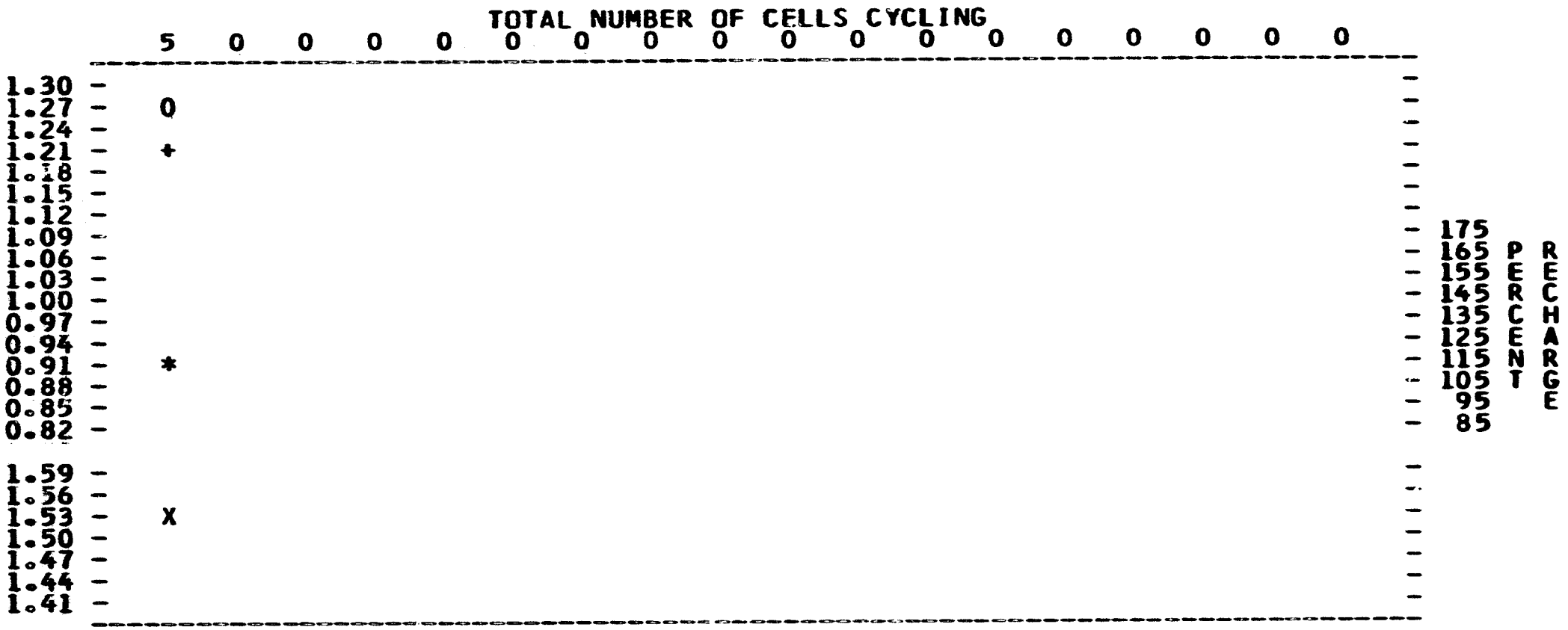
STATUS CELLS CYCLING 5
CYCLES COMPLETED 10941

CAPACITY CHECK CYCLES
740, 1611, 2468, 3220, 4031
4536, 5143, 6015, 6668, 7346
8318, 9173, 9839,10544,

FIGURE 7(B)

KEY: 0 – AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ – AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* – PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X – AVERAGE CELL VOLTAGE AT END OF CHARGE

QE/C 68-138

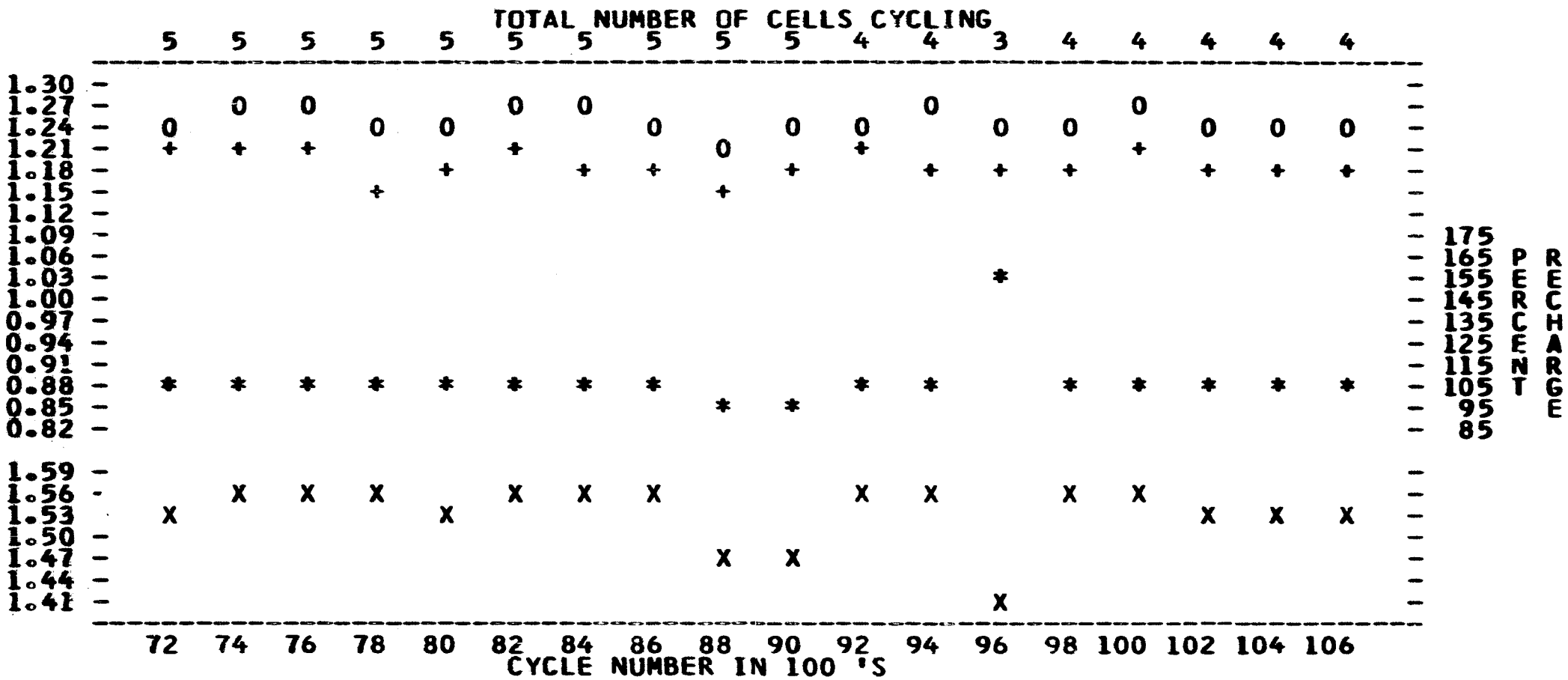



| POS. NO. | CYCLE FAILED | | | CAPACITY CHECK CYCLES |
|---|---|---|---|---|
| | | PACK NUMBER | 080A | 740, 1611, 2468, 3220, 4031 |
| | | TYPE OF CELLS | GOULD 20.00 AH | 4536, 5143, 6015, 6668, 7346 |
| | | TEST TEMPERATURE | 00 DEGREES C. | 8318, 9173, 9839,10544, |
| | | ORBIT PERIOD | 03.0 HOURS | |
| | | DEPTH OF DISCHARGE | 15 PERCENT | |
| | | SPECIFIED CHARGE RATE | 1.38 AMP. | |
| | | STATUS | CELLS CYCLING 5 | |
| | | | CYCLES COMPLETED 10941 | |

FIGURE 7(B) (CONTD)

KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE

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POS. NO. 03
CYCLE FAILED 9110

PACK NUMBER 094A
TYPE OF CELLS GOULD 20.00 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 03.0 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 2.30 AMP.

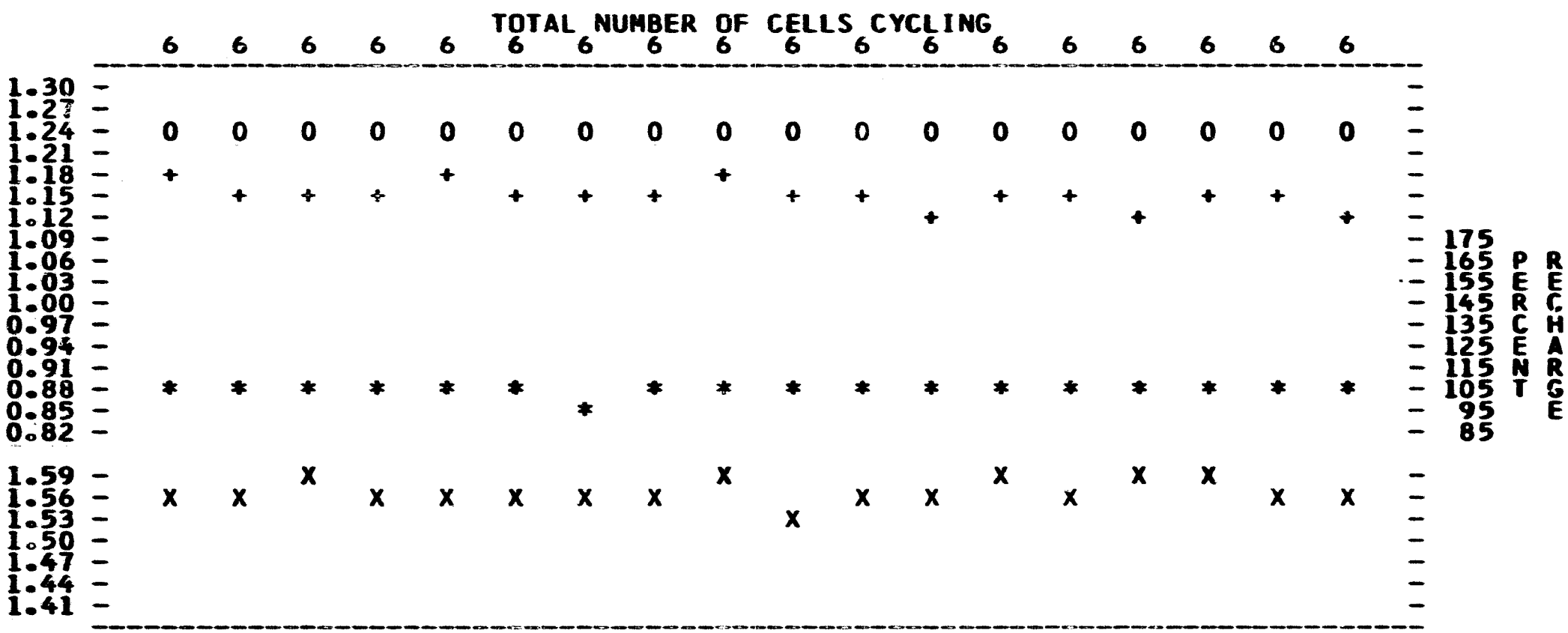
STATUS CELLS CYCLING
CYCLES COMPLETED 10725

CAPACITY CHECK CYCLES
727, 1506, 2173, 2908, 3605
4352, 4915, 5690, 6496, 7174
8185, 9002, 9495, 10216,

FIGURE 7(C)

KEY: 0 – AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ – AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* – PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X – AVERAGE CELL VOLTAGE AT END OF CHARGE

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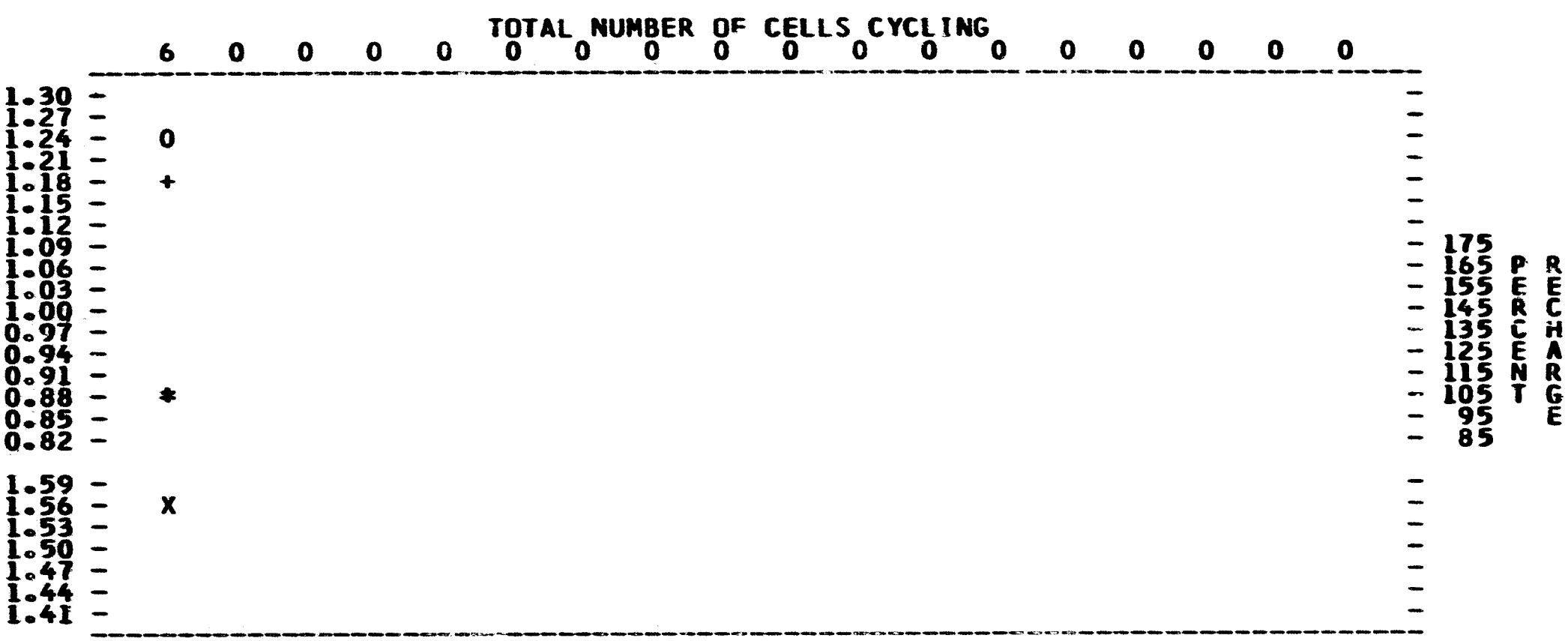

| POS. NO. | CYCLE FAILED | PACK NUMBER | 062A | CAPACITY CHECK CYCLES |
|---|---|---|---|---|
| 10 | 2995 | TYPE OF CELLS | GULTON 6.00 AH | 1386, 2741, 4090, 5647, 7050 |
| 04 | 4066 | TEST TEMPERATURE | 0 DEGREES C. | 8369, 9547,11620,12776,14164 |
| 05 | 4441 | ORBIT PERIOD | 01.5 HOURS | 15865,17508,18917,20178, |
| 07 | 8590 | DEPTH OF DISCHARGE | 25 PERCENT | |
| | | SPECIFIED CHARGE RATE | 1.72 AMP. | |

STATUS CELLS CYCLING 6
CYCLES COMPLETED 21851

FIGURE 8(A)

KEY: 0 – AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ – AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* – PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X – AVERAGE CELL VOLTAGE AT END OF CHARGE

QE/C 68-138



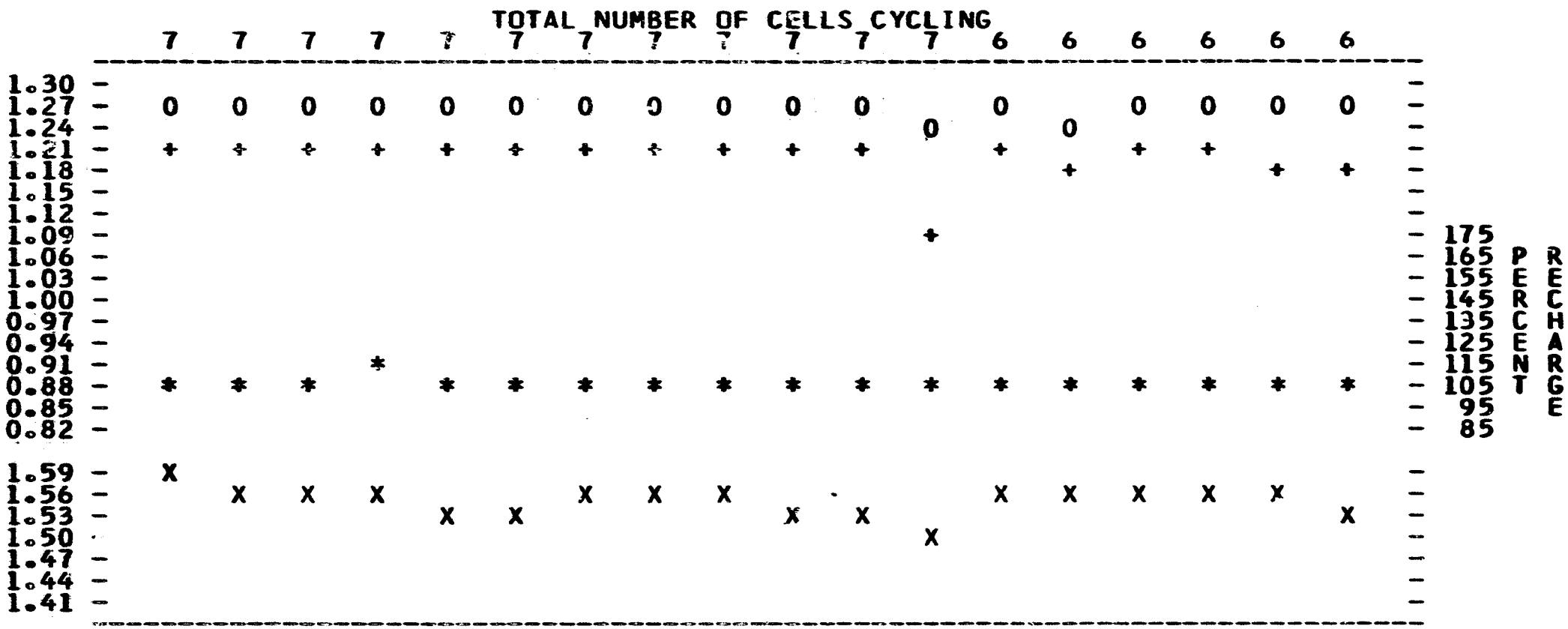

| POS. | NO. | CYCLE FAILED | | CAPACITY CHECK CYCLES |
|---|---|---|---|---|
| | 10 | 2995 | PACK NUMBER 062A | 1386, 2741, 4090, 5647, 7050 |
| | 04 | 4066 | TYPE OF CELLS GULTON 6.00 AH | 8369, 9547,11620,12776,14164 |
| | 05 | 4441 | TEST TEMPERATURE 00 DEGREES C. | 15865,17508,18917,20178, |
| | 07 | 8590 | ORBIT PERIOD 01.5 HOURS | |
| | | | DEPTH OF DISCHARGE 25 PERCENT | |
| | | | SPECIFIED CHARGE RATE 1.72 AMP. | |

STATUS CELLS CYCLING 6
CYCLES COMPLETED 21851

FIGURE 8(A) (CONTD)

KEY: 0 – AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ – AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* – PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X – AVERAGE CELL VOLTAGE AT END OF CHARGE

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| POS. NO. | CYCLE FAILED |
|---|---|
| 04 | 5012 |
| 06 | 5706 |
| 08 | 9407 |
| 05 | 9431 |

PACK NUMBER 065A
TYPE OF CELLS GULTON 6.0C AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 03.0 HOURS
DEPTH OF DISCHARGE 15 PERCENT
SPECIFIED CHARGE RATE 0.41 AMP.

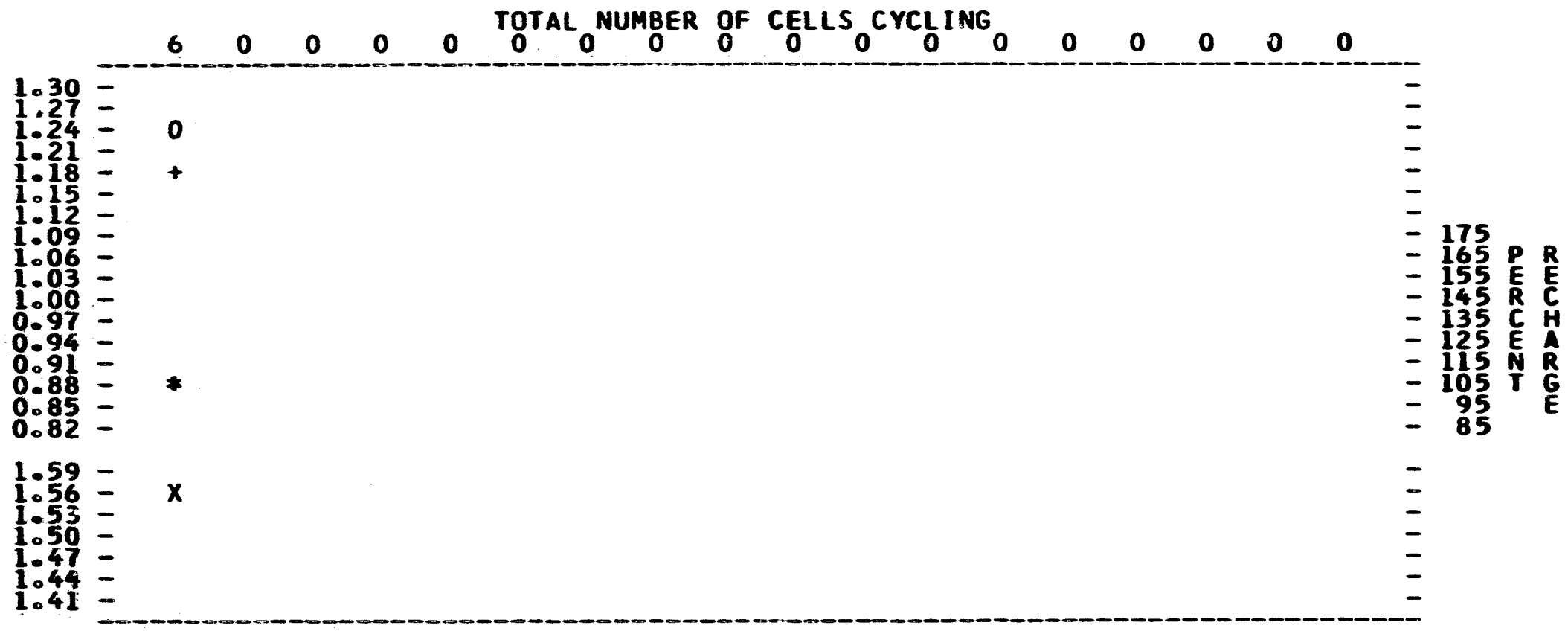
STATUS CELLS CYCLING 6
CYCLES COMPLETED 10781

CAPACITY CHECK CYCLES
694, 1440, 2200, 2899, 3555
4404, 4986, 5743, 6323, 7045
7979, 8724, 9455,10048,

FIGURE 8(B)

KEY: 0 – AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ – AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* – PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X – AVERAGE CELL VOLTAGE AT END OF CHARGE

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| POS. NO. | CYCLE FAILED |
|---|---|
| 04 | 5012 |
| 06 | 5706 |
| 08 | 9407 |
| 05 | 9431 |

PACK NUMBER 065A
TYPE OF CELLS GULTON 6.00 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 03.0 HOURS
DEPTH OF DISCHARGE 15 PERCENT
SPECIFIED CHARGE RATE 0.41 AMP.

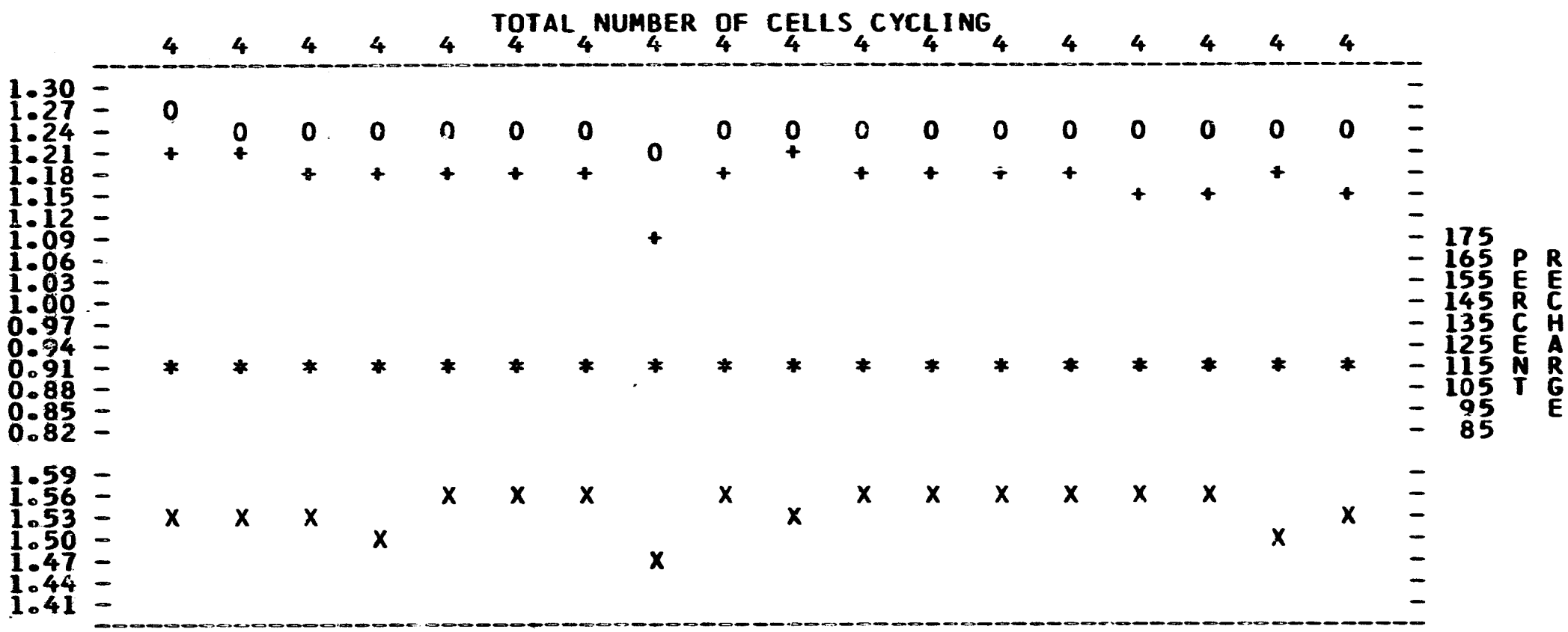
CAPACITY CHECK CYCLES
694, 1440, 2200, 2899, 3555
4404, 4986, 5743, 6323, 7045
7979, 8724, 9455,10048,

STATUS CELLS CYCLING 6
CYCLES COMPLETED 10781

FIGURE 8(B) (CONTD)

KEY: 0 – AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ – AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* – PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X – AVERAGE CELL VOLTAGE AT END OF CHARGE

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POS. NO. 02

CYCLE FAILED 135

PACK NUMBER 102A
TYPE OF CELLS GULTON 20.00 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 03.0 HOURS
DEPTH OF DISCHARGE 15 PERCENT
SPECIFIED CHARGE RATE 1.38 AMP.

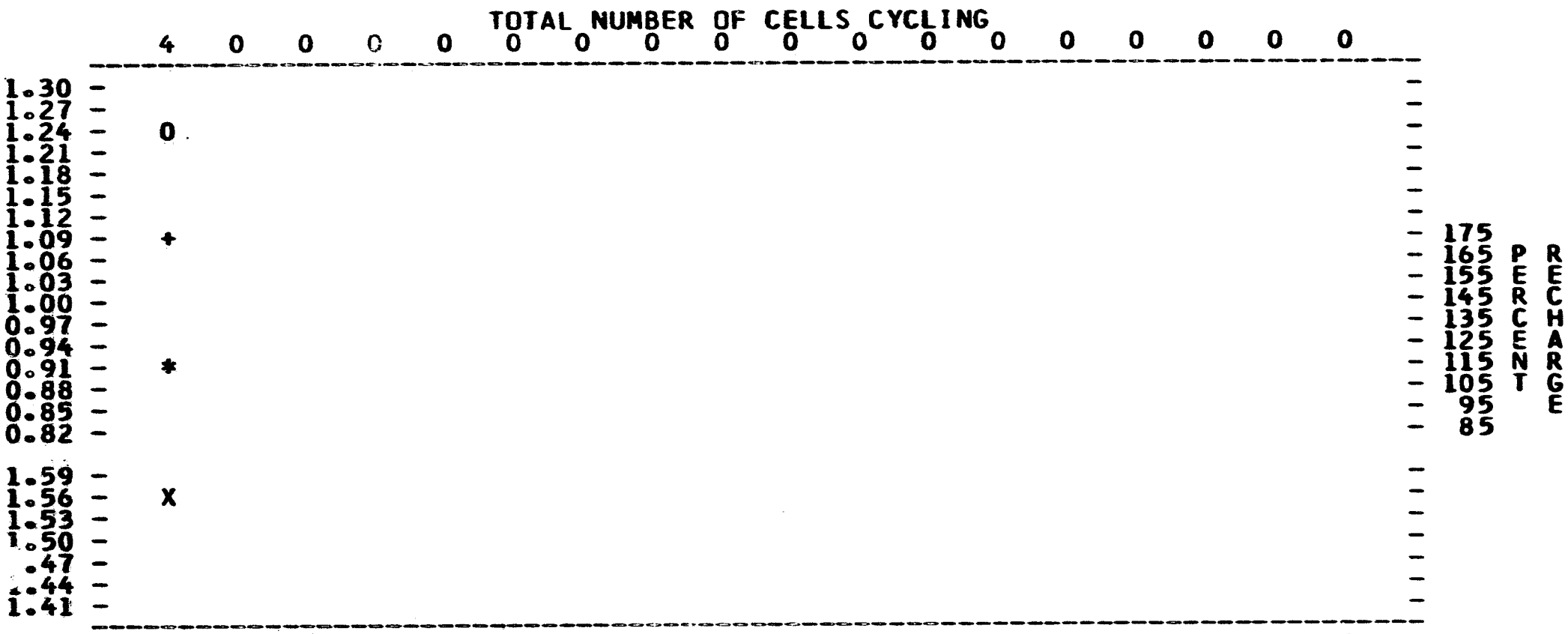
STATUS CELLS CYCLING 4
CYCLES COMPLETED 10776

CAPACITY CHECK CYCLES
716, 1437, 2104, 2839, 3536
4364, 4971, 5843, 6496, 7174
8153, 9009, 9025, 9674,

FIGURE 9(A)

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KEY: 0 – AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ – AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* – PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X – AVERAGE CELL VOLTAGE AT END OF CHARGE



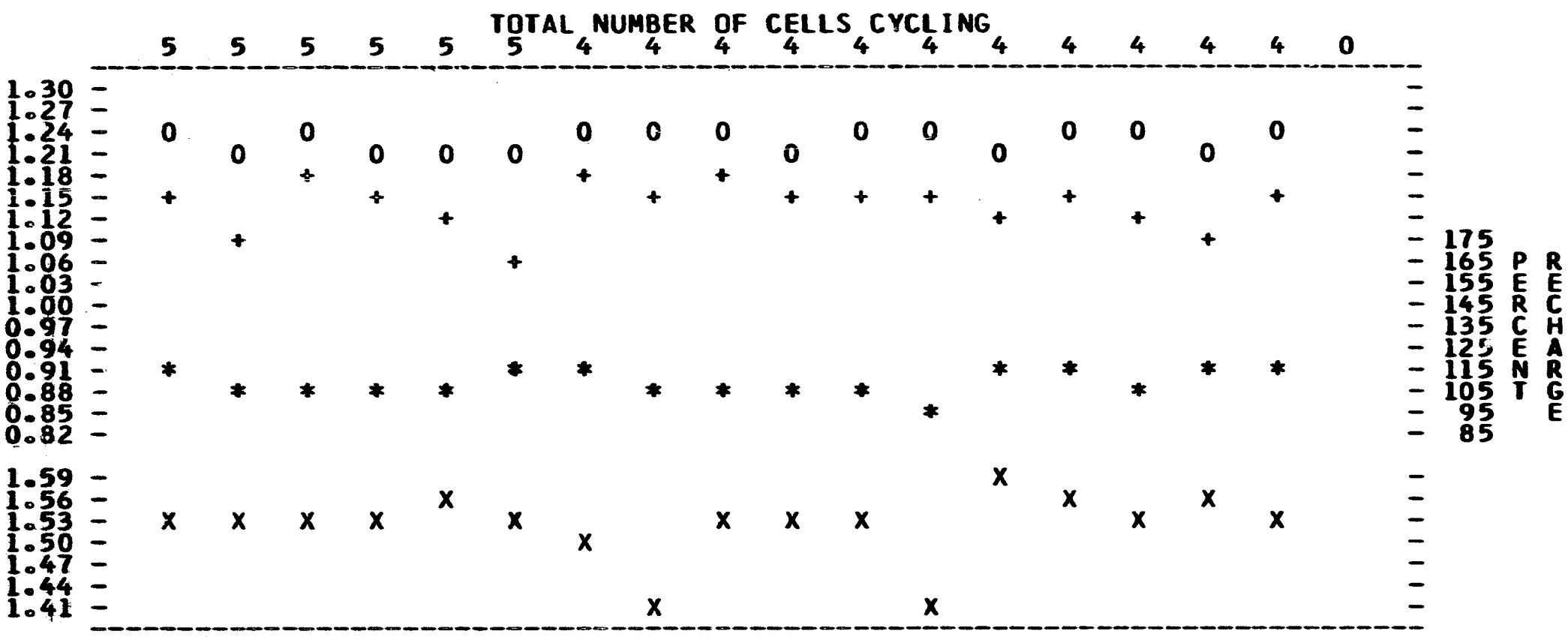

| POS. NO. | CYCLE FAILED | | |
|---|---|---|---|
| 02 | 135 | PACK NUMBER | 102A |
| | | TYPE OF CELLS | GULTON 20.00 AH |
| | | TEST TEMPERATURE | 00 DEGREES C. |
| | | ORBIT PERIOD | 03.0 HOURS |
| | | DEPTH OF DISCHARGE | 15 PERCENT |
| | | SPECIFIED CHARGE RATE | 1.38 AMP. |
| | | STATUS | CELLS CYCLING 4 |
| | | | CYCLES COMPLETED 10776 |

CAPACITY CHECK CYCLES
716, 1437, 2104, 2839, 3536
4364, 4971, 5843, 6496, 7174
8153, 9009, 9025, 9674,

FIGURE 9(A) (CONTD)

KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE

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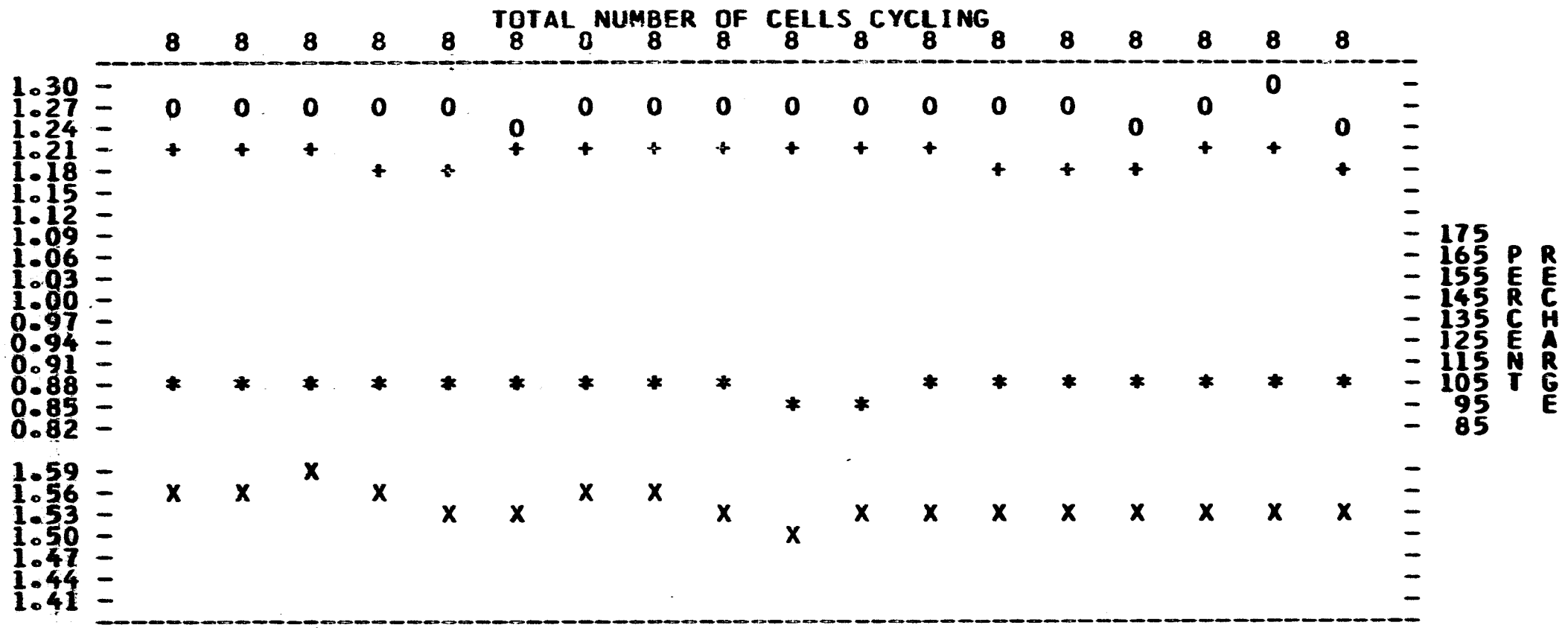



| POS. NO. | CYCLE FAILED | | CAPACITY CHECK CYCLES |
|---|---|---|---|
| 03 | 8274 | PACK NUMBER 116A | 760, 1357, 2017, 2750, 3393 |
| | | TYPE OF CELLS GULTON 20.00 AH | 4147, 4703, 5478, 6284, 6962 |
| | | TEST TEMPERATURE 00 DEGREES C. | 7956, 8712, 9305, 10026, |
| | | ORBIT PERIOD 03.0 HOURS | |
| | | DEPTH OF DISCHARGE 25 PERCENT | |
| | | SPECIFIED CHARGE RATE 2.30 AMP. | |
| | | STATUS CELLS CYCLING 4 | |
| | | CYCLES COMPLETED 10535 | |

FIGURE 9(B)

KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE

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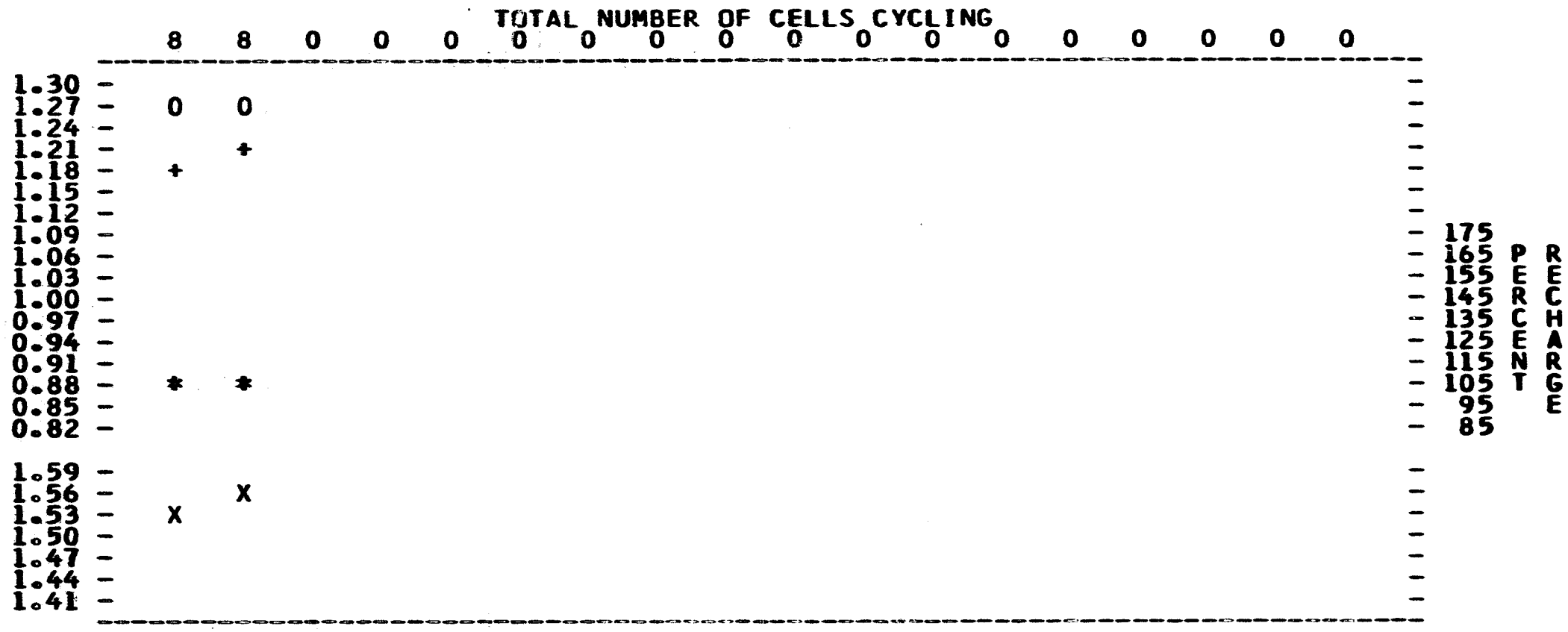

| POS. NO. | CYCLE FAILED | | |
|---|---|---|---|
| 09 | 2010 | PACK NUMBER | 049A |
| 03 | 10073 | TYPE OF CELLS | SONOTONE 5.00 AH |
| | | TEST TEMPERATURE | 00 DEGREES C. |
| | | ORBIT PERIOD | 01.5 HOURS |
| | | DEPTH OF DISCHARGE | 15 PERCENT |
| | | SPECIFIED CHARGE RATE | 0.86 AMP. |
| | | STATUS CELLS CYCLING | 8 |
| | | CYCLES COMPLETED | 22213 |

CAPACITY CHECK CYCLES
1405, 2691, 3965, 5395, 6895
8864,10010,11611,13200,14668
16422,17909,19759,21198,

FIGURE 10(A)

KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE

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| POS. NO. | CYCLE FAILED |
|---|---|
| 09 | 2010 |
| 03 | 1[illegible]73 |

PACK NUMBER 049A
TYPE OF CELLS SONOTONE 5.00 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 15 PERCENT
SPECIFIED CHARGE RATE 0.86 AMP.

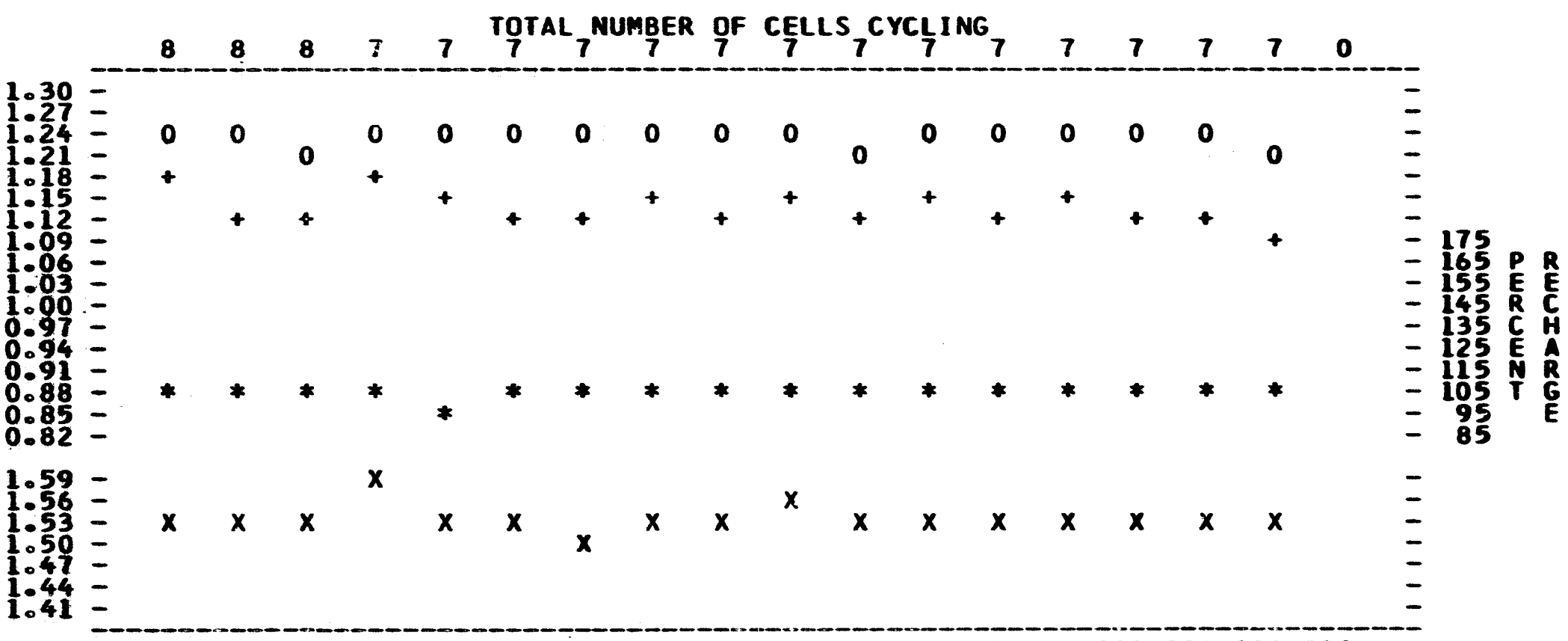
STATUS CELLS CYCLING 8
CYCLES COMPLETED 22213

CAPACITY CHECK CYCLES
1405, 2691, 3965, 5395, 6895
8864,10010,11511,13200,14668
16422,17909,19759,21198,

FIGURE 10(A) (CONTD

KEY: 0 – AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ – AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* – PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X – AVERAGE CELL VOLTAGE AT END OF CHARGE

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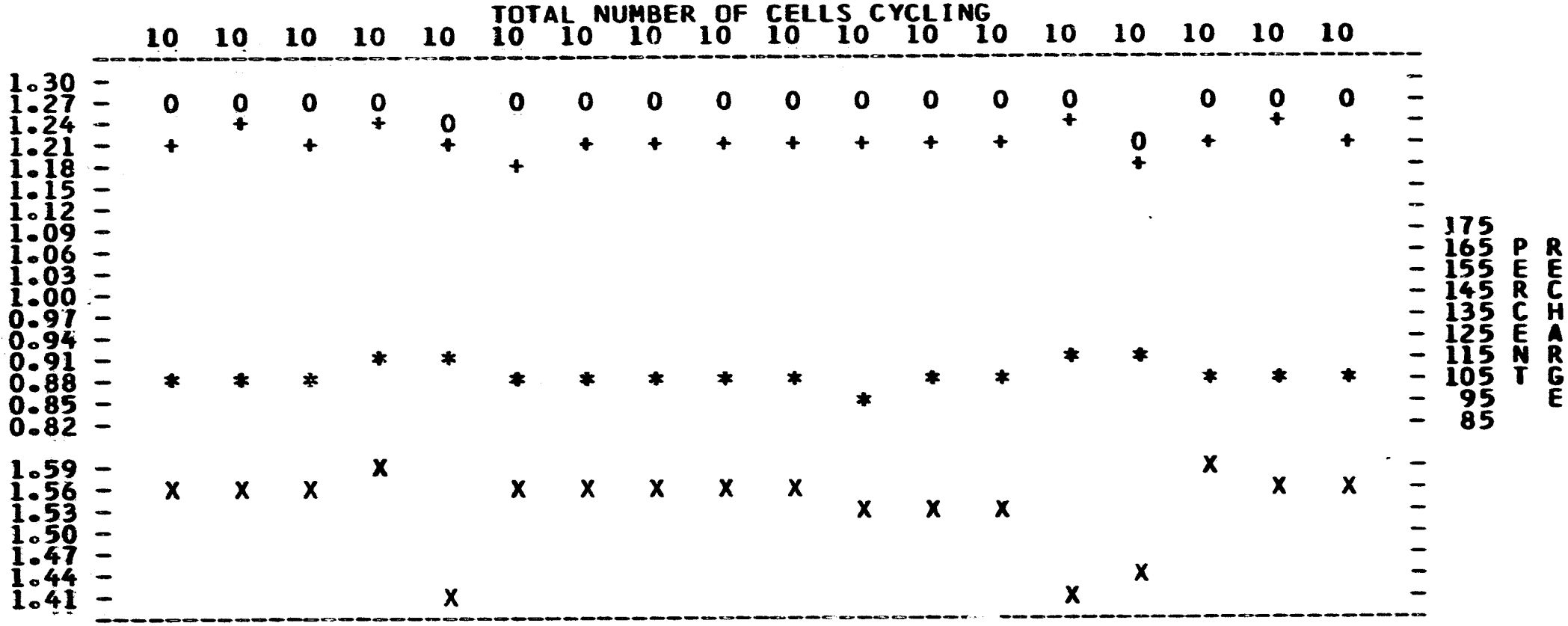

| POS. NO. | CYCLE FAILED | PACK NUMBER | 050A | CAPACITY CHECK CYCLES |
|---|---|---|---|---|
| 05 | 12069 | TYPE OF CELLS | SONOTONE 5.00 AH | 1435, 2648, 3921, 5351, 6782 |
| 03 | 13500 | TEST TEMPERATURE | 00 DEGREES C. | 8739, 9978,11691,13077,14382 |
| 04 | 15294 | ORBIT PERIOD | 01.5 HOURS | 15591,17234,18643,19903, |
| | | DEPTH OF DISCHARGE | 25 PERCENT | |
| | | SPECIFIED CHARGE RATE | 1.44 AMP. | |

STATUS CELLS CYCLING 7
CYCLES COMPLETED 21577

FIGURE 10(B)

KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE

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POS. NO. CYCLE FAILED

PACK NUMBER 053A
TYPE OF CELLS SONOTONE 5.00 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 03.0 HOURS
DEPTH OF DISCHARGE 15 PERCENT
SPECIFIED CHARGE RATE 0.35 AMP.

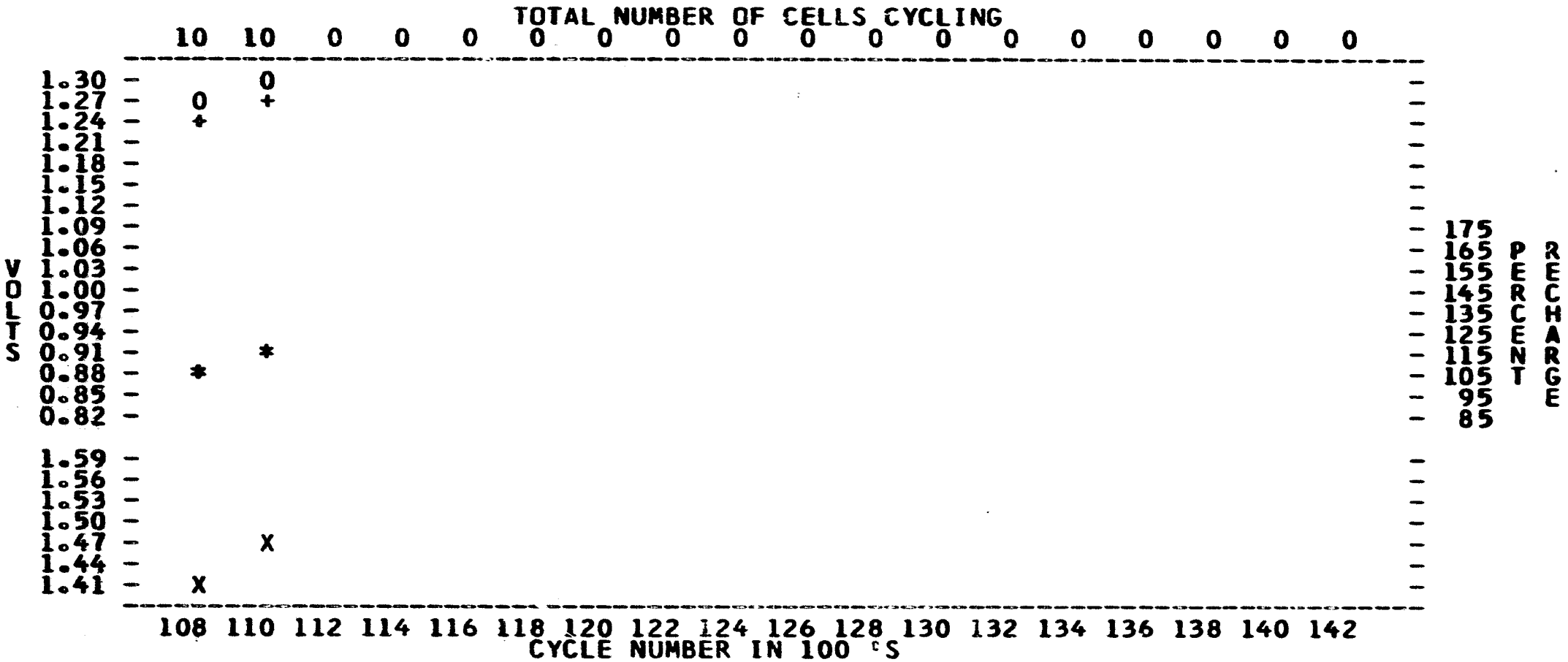
STATUS CELLS CYCLING 10
CYCLES COMPLETED 10992

CAPACITY CHECK CYCLES
702, 1332, 2068, 2767, 3423
4272, 4854, 5719, 6496, 7234
8168, 8913, 9673,10226,

FIGURE 10(C)

KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE

QE/C 68-138




POS. NO. CYCLE FAILED

PACK NUMBER 053A
TYPE OF CELLS SONOTONE 5.00 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 03.0 HOURS
DEPTH OF DISCHARGE 15 PERCENT
SPECIFIED CHARGE RATE 0.35 AMP.

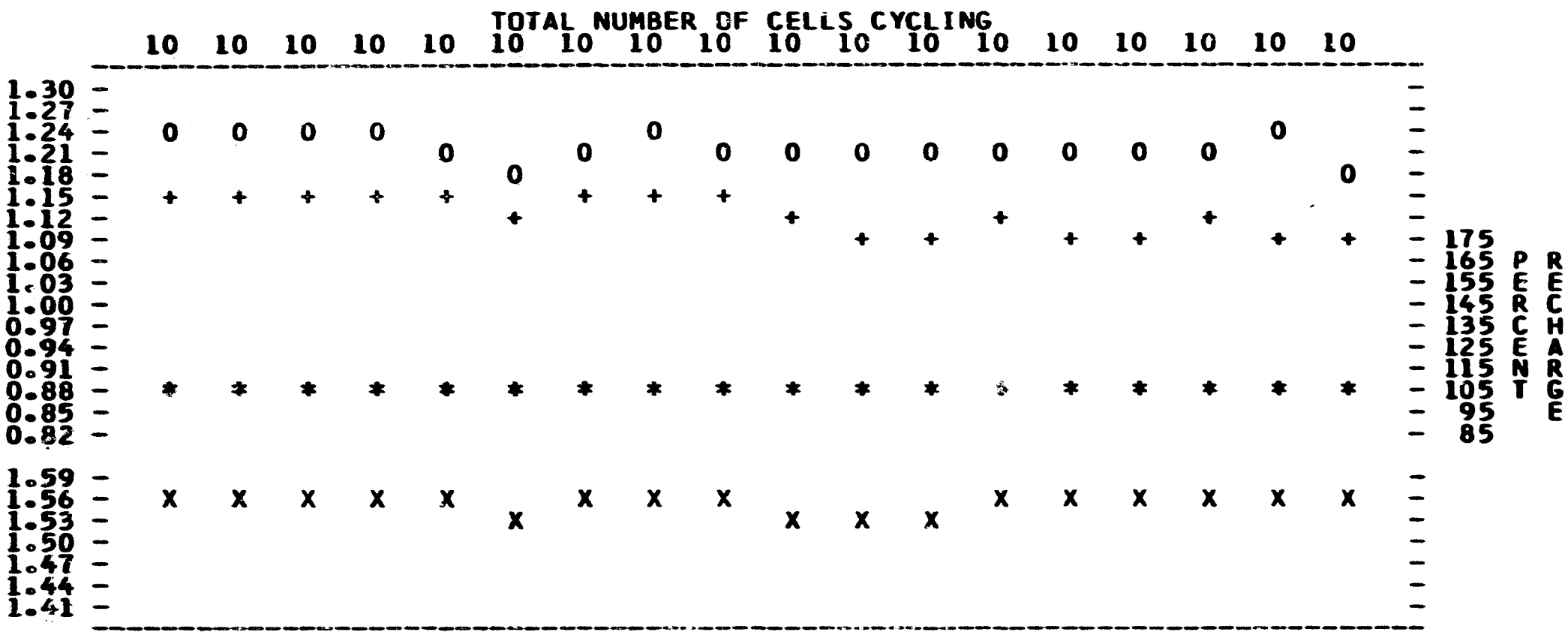
STATUS CELLS CYCLING 10
CYCLES COMPLETED 10992

CAPACITY CHECK CYCLES
702, 1332, 2068, 2767, 3423
4272, 4854, 5719, 6496, 7234
8168, 8913, 9673, 10226,

FIGURE 10(C) (CONTD)

KEY: 0 – AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ – AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* – PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X – AVERAGE CELL VOLTAGE AT END OF CHARGE

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POS. NO. CYCLE FAILED

PACK NUMBER 054A
TYPE OF CELLS SONOTONE 5.00 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 03.0 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 0.58 AMP.

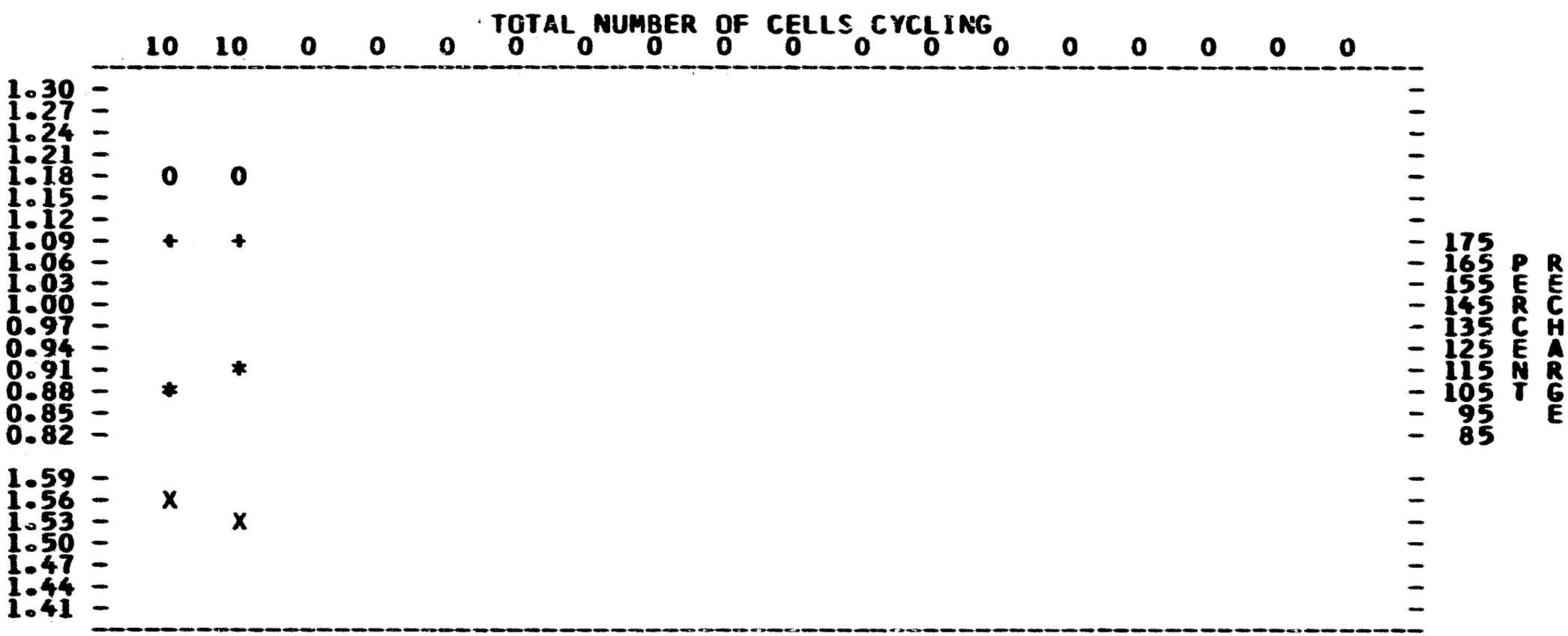
STATUS CELLS CYCLING 10
CYCLES COMPLETED 10952

CAPACITY CHECK CYCLES
701, 1310, 1984, 2681, 3433
4242, 4876, 5693, 6378, 7100
7886, 8721, 9465,10074,

FIGURE 10(D)

KEY: 0 – AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ – AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* – PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X – AVERAGE CELL VOLTAGE AT END OF CHARGE

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POS. NO. CYCLE FAILED

PACK NUMBER 054A
TYPE OF CELLS SONOTONE 5.00 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 03.0 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 0.58 AMP.

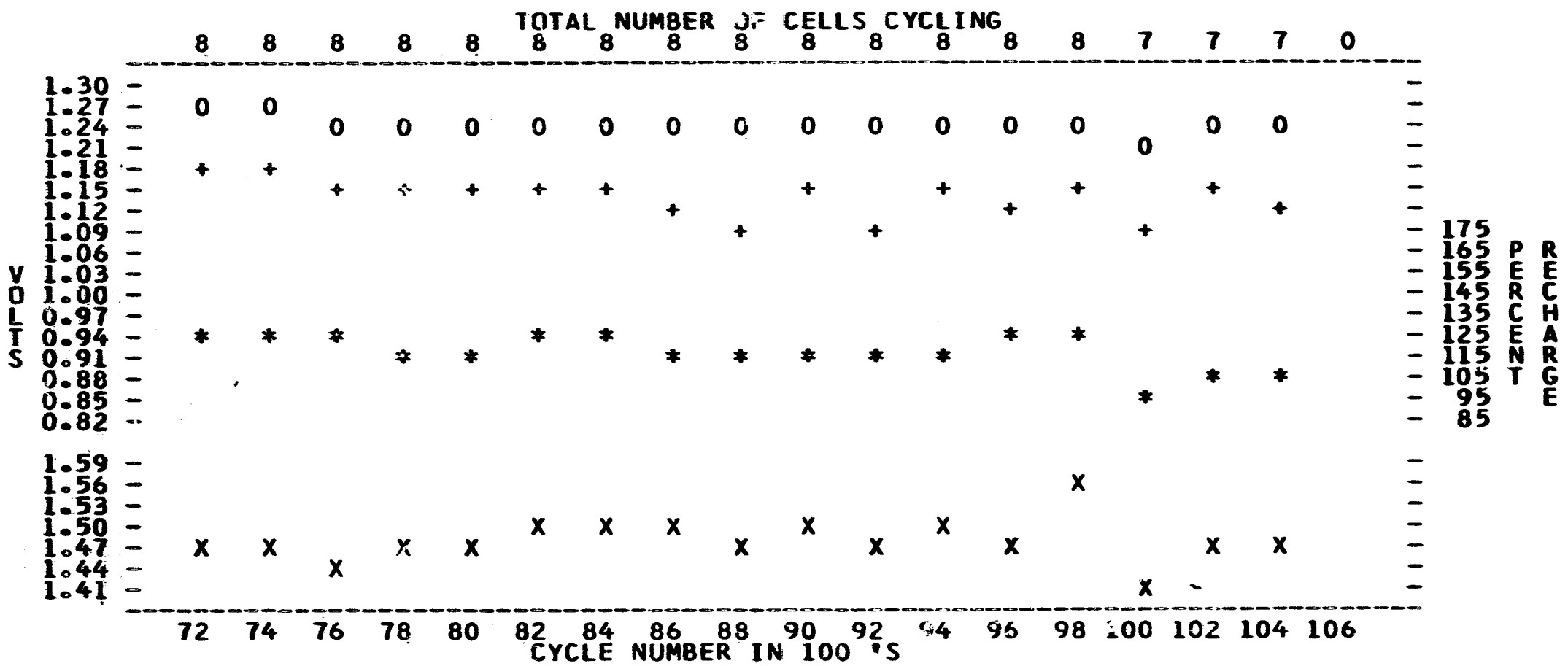
STATUS CELLS CYCLING 10
CYCLES COMPLETED 10952

CAPACITY CHECK CYCLES
701, 1310, 1984, 2681, 3433
4242, 4876, 5693, 6378, 7100
7886, 8721, 9465,10074,

FIGURE 10(D) (CONTD)

KEY: 0 – AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ – AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* – PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X – AVERAGE CELL VOLTAGE AT END OF CHARGE

QE/C 68-138




| POS. | NO. | CYCLE FAILED | PACK NUMBER | 005A | CAPACITY CHECK CYCLES |
|---|---|---|---|---|---|
| | 02 | 3134 | TYPE OF CELLS | SONOTONE 5.00 AH | 702, 1368, 2125, 2823, 3437 |
| | 03 | 5272 | TEST TEMPERATURE | 25 DEGREES C. | 4220, 4794, 5562, 6356, 7065 |
| | 01 | 9971 | ORBIT PERIOD | 03.0 HOURS | 8023, 9583,10027, |
| | | | DEPTH OF DISCHARGE | 25 PERCENT | |
| | | | SPECIFIED CHARGE RATE | 0.62 AMP. | |
| | | | STATUS | CELLS CYCLING 7 | |
| | | | | CYCLES COMPLETED 10664 | |

CYCLE 3134: POS.2 FAILED: PUT BACK IN PACK ON CYCLE 3625 AFTER REGAINING NORMAL CAPACITY DURING FAILURE TEST.IT COMPLETED 146 ADDITIONAL SATISFACTORY CYCLES AT WHICH TIME PACK COMPLETED 4262 CYCLES.

FIGURE 10(E)

C. Performance at 50° C; Four Packs Held at 50° C:

1. Initially, the 28 packs assigned to the high temperature environment began cycling at 50° C. At the 25 percent depth of discharge, end-of-discharge voltages dropped steadily. Five cells failed within the first month of continuous cycling at that temperature. Among the Gulton 6.0 ah cells at 15 percent depth of discharge, end-of-discharge voltages also dropped and one cell failed. Earlier tests had indicated that, because charge acceptance is relatively inefficient at 50° C, the 25 percent depth of discharge was close to the maximum capacity that could be realized by many of the cell types under the prescribed cycling conditions. In addition, the separator materials were known to become unstable at temperatures somewhat above 40° C, so that separator deterioration was greatly accelerated. An ambient temperature of 40° C is the maximum recommended by the manufacturers.

2. In an attempt to maintain cycling at 50° C the percent of recharge for Pack 42A (Gulton 6.0 ah, 25 percent depth, 3-hour orbit) was raised after 74 cycles to 200 percent by increasing the charge rate from c/6.25 to c/5. After 22 cycles at the new charge rate a cell failed and the attempt was discontinued.

3. Therefore, after having completed from 4.0 to 48.7 days of continuous cycling, all but four of the 28 high-temperature packs were moved to a 40° C ambient temperature. The four packs retained at 50° C ambient temperature and the cycles completed are given below:

| Pack Number | Cell Type | Orbit Period | Cycles at 50° C | Additional Cycles at 40° C | Total Cycles to Pack Failure |
|---|---|---|---|---|---|
| 40A | G.E. 3.0 ah | 1.5 hr | 1440 | 1069 | 2509 |
| 32A | Gould 3.5 ah | 3 hr | 495 | 479 | 974 |
| 126A | Gould 20 ah | 1.5 hr | 1326 | 243 | 1569 |
| 122A | Gould 20 ah | 3 hr | 756 | 227 | 983 |

Depth of Discharge: 25 percent for all four packs.

D. Cell Temperatures:

1. Table IV gives a typical temperature range which occurred during discharge and charge for each of the 84 packs. These are readings from the thermocouples soldered to the positive terminals of the cells, and were taken the month of December 1966 or the last month of cycling for those packs that failed earlier. Other checks have been made of the temperatures taken during the months of March 1964 and December 1965. The temperatures listed in each case are the maximum for any cell in the pack, and the minimum for any cell in the pack.

2. At 25° C the cells are exposed directly to the moving air of the room. The midpoint of the temperature range at the positive terminals is usually from 5° C to 10° C above ambient. Generally, for each type, the packs at the 40 percent depth of discharge show temperatures 3° C to 5° C higher than those at 25 percent depth, and at each depth the range for the 1.5-hour orbit is slightly higher than for the 3-hour orbit. A comparison of the three temperature checks revealed that the temperature range had not changed.

3. At 0° C and 40° C the thermocouples are exposed to the rapidly moving air in the temperature chambers, which may account for the fact that the differences which had been observed at 25° C are less apparent. Thermocouple temperatures in the 0° C environment averaged 1° C to 2° C above ambient, with the maximum temperature rise (8° C to 9° C) being shown by the Gould 20 a.h. packs cycling at 1.5 hours. A comparison of the three temperature checks revealed that the temperature range had not changed. The majority of packs in the 40° C environment showed almost no rise in average thermocouple temperature above ambient. The four packs which were held at 50° C showed almost no rise in the average thermocouple temperature above ambient. The maximum temperature rises noted at 40° C were for packs operating at the 25 percent depth of discharge and 1.5-hour orbit period, and ranged from 44.3° C to 52.3° C. The December 1966 check showed that the March 1964 and December 1965 temperatures were typical for this ambient temperature with one exception. The Gould 20 a.h. pack (Pack 112A) operating at 15 percent depth of discharge and 3-hour orbit had a maximum temperature of 42.7° C in March 1964 but increased to 54.3° C by December 1965 and remained that high until the pack failed.

## TABLE IV

### TYPICAL RANGE OF PACK TEMPERATURE READINGS

| Pack Number | Ambient Temperature °C | Percent Depth of Discharge | Orbit Period (Hours) | Temperatures | | | |
|---|---|---|---|---|---|---|---|
| | | | | Discharge | | Charge | |
| | | | | Max. | Min. | Max. | Min. |
| | | | G.E. 3.0 ah | | | | |
| 63A | 0 | 15 | 1.5 | 4.0 | 0.6 | 4.2 | 0.4 |
| 67A | 0 | 15 | 3 | 2.8 | -2.7 | 4.0 | -3.1 |
| 64A | 0 | 25 | 1.5 | 2.2 | -1.3 | 2.8 | -1.1 |
| 68A | 0 | 25 | 3 | 3.4 | -1.1 | 2.8 | -1.7 |
| 15A | 25 | 25 | 1.5 | 31.4 | 27.8 | 31.5 | 27.5 |
| 19A | 25 | 25 | 3 | 27.9 | 25.3 | 28.3 | 23.6 |
| 16A | 25 | 40 | 1.5 | 36.5 | 28.3 | 36.8 | 28.8 |
| 20A | 25 | 40 | 3 | 35.0 | 29.5 | 34.1 | 27.9 |
| 39A | 40 | 15 | 1.5 | 41.9 | 39.5 | 31.9 | 39.8 |
| 43A | 40 | 15 | 3 | 42.2 | 40.2 | 42.0 | 38.2 |
| 40A | 50 | 25 | 1.5 | 52.3 | 48.3 | 52.3 | 49.5 |
| 44A | 40 | 25 | 3 | 44.7 | 41.5 | 43.7 | 39.6 |
| | | | G.E. 12 ah | | | | |
| 110A | 0 | 15 | 1.5 | 2.8 | -2.5 | 1.4 | -2.5 |
| 111A | 0 | 15 | 3 | 3.3 | -0.9 | 3.2 | -3.1 |
| 124A | 0 | 25 | 1.5 | 3.2 | -3.5 | 3.1 | -0.9 |
| 125A | 0 | 25 | 3 | 4.0 | 0.2 | 3.2 | -1.1 |
| 82A | 25 | 25 | 1.5 | 30.0 | 26.0 | 30.5 | 27.1 |
| 83A | 25 | 25 | 3 | 32.0 | 26.0 | 30.4 | 23.8 |
| 96A | 25 | 40 | 1.5 | 35.4 | 29.8 | 36.4 | 30.2 |
| 97A | 25 | 40 | 3 | 35.0 | 27.5 | 35.8 | 25.8 |
| 85A | 40 | 15 | 1.5 | 41.6 | 37.5 | 40.8 | 37.6 |
| 86A | 40 | 15 | 3 | 41.9 | 38.1 | 41.0 | 38.1 |
| 99A | 40 | 25 | 1.5 | 47.3 | 41.4 | 47.3 | 40.1 |
| 100A | 40 | 25 | 3 | 44.8 | 39.6 | 42.9 | 39.2 |

TABLE IV (Contd)

TYPICAL RANGE OF PACK TEMPERATURE READINGS

| Pack Number | Ambient Temperature °C | Percent Depth of Discharge | Orbit Period (Hours) | Temperatures Discharge Max. | Discharge Min. | Charge Max. | Charge Min. |
|---|---|---|---|---|---|---|---|
| | | | Gould 3.5 ah | | | | |
| 51A | 0 | 15 | 1.5 | 4.3 | 0.4 | 4.2 | 1.1 |
| 55A | 0 | 15 | 3 | 3.5 | -0.7 | 3.0 | -2.8 |
| 52A | 0 | 25 | 1.5 | 5.2 | 0.6 | 4.4 | -0.8 |
| 56A | 0 | 25 | 3 | 4.8 | -1.1 | 4.2 | -2.8 |
| 3A | 25 | 25 | 1.5 | 42.1 | 29.8 | 41.9 | 30.2 |
| 7A | 25 | 25 | 3 | 31.6 | 27.7 | 32.0 | 26.7 |
| 4A | 25 | 40 | 1.5 | 41.6 | 31.5 | 40.0 | 31.2 |
| 8A | 25 | 40 | 3 | 40.0 | 31.5 | 40.8 | 27.9 |
| 27A | 40 | 15 | 1.5 | 43.5 | 40.6 | 42.9 | 40.0 |
| 31A | 40 | 15 | 3 | 42.7 | 39.5 | 41.6 | 37.9 |
| 28A | 40 | 25 | 1.5 | 40.0 | 37.6 | 40.0 | 36.2 |
| 32A | 40 | 25 | 3 | 45.4 | 42.7 | 44.8 | 40.0 |
| | | | Gould 20 ah | | | | |
| 84A | 0 | 15 | 1.5 | 8.8 | 1.1 | 8.2 | 0.8 |
| 80A | 0 | 15 | 3 | 4.0 | -2.7 | 2.0 | -1.3 |
| 98A | 0 | 25 | 1.5 | 9.2 | -1.3 | 8.0 | -0.9 |
| 94A | 0 | 25 | 3 | 3.0 | -3.9 | 3.1 | -1.1 |
| 104A | 25 | 25 | 1.5 | 28.3 | 27.2 | 28.5 | 27.3 |
| 105A | 25 | 25 | 3 | 30.6 | 25.8 | 30.0 | 23.7 |
| 118A | 25 | 40 | 1.5 | 42.9 | 37.5 | 42.7 | 37.9 |
| 119A | 25 | 40 | 3 | 39.6 | 31.2 | 37.0 | 27.9 |
| 112A | 40 | 15 | 1.5 | 41.6 | 36.0 | 42.1 | 36.8 |
| 108A | 40 | 15 | 3 | 54.3 | 49.3 | 50.8 | 48.5 |
| 126A | 50 | 25 | 1.5 | 51.4 | 49.1 | 51.0 | 49.4 |
| 122A | 50 | 25 | 3 | 55.0 | 49.6 | 51.4 | 49.6 |

TABLE IV (Contd)

TYPICAL RANGE OF PACK TEMPERATURE READINGS

| Pack Number | Ambient Temperature °C | Percent Depth of Discharge | Orbit Period (Hours) | Temperatures Discharge Max. | Discharge Min. | Charge Max. | Charge Min. |
|---|---|---|---|---|---|---|---|
| | | | Gulton 6.0 ah | | | | |
| 61A | 0 | 15 | 1.5 | 3.4 | -2.9 | 3.1 | -3.3 |
| 65A | 0 | 15 | 3 | 4.4 | 1.1 | 6.0 | -1.5 |
| 62A | 0 | 25 | 1.5 | 2.8 | -0.3 | 4.0 | -1.2 |
| 66A | 0 | 25 | 3 | 4.8 | -0.7 | 4.0 | -0.7 |
| 13A | 25 | 25 | 1.5 | 31.5 | 26.5 | 31.8 | 27.3 |
| 17A | 25 | 25 | 3 | 31.9 | 26.8 | 31.4 | 25.0 |
| 14A | 25 | 40 | 1.5 | 33.3 | 28.7 | 36.1 | 28.5 |
| 18A | 25 | 40 | 3 | 35.6 | 27.3 | 36.0 | 26.8 |
| 37A | 40 | 15 | 1.5 | 45.6 | 39.3 | 46.0 | 37.6 |
| 41A | 40 | 15 | 3 | 44.6 | 40.8 | 44.6 | 40.0 |
| 38A | 40 | 25 | 1.5 | 44.8 | 40.9 | 45.9 | 41.0 |
| 42A | 40 | 25 | 3 | 40.8 | 37.9 | 41.7 | 38.0 |
| | | | Gulton 20 ah | | | | |
| 101A | 0 | 15 | 1.5 | 3.2 | -1.9 | 4.0 | -0.7 |
| 102A | 0 | 15 | 3 | 3.2 | -4.1 | 1.2 | -2.8 |
| 115A | 0 | 25 | 1.5 | 4.8 | -0.7 | 5.4 | 2.8 |
| 116A | 0 | 25 | 3 | 3.3 | -2.8 | 2.8 | -3.3 |
| 73A | 25 | 25 | 1.5 | 30.3 | 27.3 | 32.5 | 26.2 |
| 74A | 25 | 25 | 3 | 31.2 | 26.0 | 31.8 | 27.3 |
| 87A | 25 | 40 | 1.5 | 42.9 | 38.0 | 44.2 | 38.1 |
| 88A | 25 | 40 | 3 | 36.2 | 25.4 | 38.0 | 26.2 |
| 76A | 40 | 15 | 1.5 | 41.9 | 40.0 | 42.0 | 39.6 |
| 77A | 40 | 15 | 3 | 41.9 | 38.1 | 42.0 | 37.7 |
| 90A | 40 | 25 | 1.5 | 42.7 | 38.8 | 42.9 | 38.1 |
| 91A | 40 | 25 | 3 | 43.5 | 39.5 | 45.8 | 41.4 |

## TABLE IV (Contd)

### TYPICAL RANGE OF PACK TEMPERATURE READINGS

| Pack Number | Ambient Temperature °C | Percent Depth of Discharge | Orbit Period (Hours) | Temperatures | | | |
|---|---|---|---|---|---|---|---|
| | | | | Discharge | | Charge | |
| | | | | Max. | Min. | Max. | Min. |
| | | | Sonotone 5.0 ah | | | | |
| 49A | 0 | 15 | 1.5 | 2.0 | -2.3 | 3.2 | -1.9 |
| 53A | 0 | 15 | 3 | 6.0 | 1.3 | 6.0 | -0.8 |
| 50A | 0 | 25 | 1.5 | 3.3 | -0.7 | 2.8 | -0.3 |
| 54A | 0 | 25 | 3 | 4.0 | -2.9 | 1.2 | -3.9 |
| 1A | 25 | 25 | 1.5 | 39.6 | 34.5 | 39.1 | 34.1 |
| 5A | 25 | 25 | 3 | 34.2 | 29.1 | 34.3 | 28.3 |
| 2A | 25 | 40 | 1.5 | 38.1 | 27.3 | 38.1 | 32.7 |
| 6A | 25 | 40 | 3 | 36.0 | 29.6 | 37.0 | 29.3 |
| 25A | 40 | 15 | 1.5 | 45.8 | 38.0 | 46.0 | 38.4 |
| 29A | 40 | 15 | 3 | 43.9 | 41.2 | 44.1 | 40.0 |
| 26A | 40 | 25 | 1.5 | 48.9 | 39.3 | 45.0 | 37.9 |
| 30A | 40 | 25 | 3 | 44.6 | 41.2 | 44.8 | 41.0 |

**E. Cell Failures:**

1. Cell failures are discussed below, with detailed results of the failure analyses shown in Tables Va through Vg.

2. Special Considerations:

a. The charge rates specified in the cycling program usually exceeded the maximum rates recommended by the manufacturers. For example, packs which are cycling in a 1.5-hour orbit at 25° C, 40 percent depth of discharge are being charged at the c/2 rate, although the maximum charge rate recommended by the manufacturers is c/10. The only charge rates below c/10 are those for the 3-hour orbit, 15 percent depth of discharge combinations, the rates for which are calculated to be c/14.5 at 0° C and c/10.4 at 40° C.

b. These cells were manufactured prior to January 1963. Because of subsequent changes in construction, newer cells of the same capacity and manufacturer may not show the characteristics discussed here. Also, the manufacturers have reported that corrective action has been taken to eliminate the sources of premature mechanical failure.

3. Definition and Description of Terms; Symbols Used in Tables Va through Vg:

a. In order to clarify the discussion that follows, all terms are defined according to their use in this report. These are our definitions, and they may differ somewhat from usage elsewhere. Full descriptions are also included in order to simplify the remainder of the discussion.

b. The symbols used in Tables Va through Vg are explained with the column headings under which they are found. A given letter may differ in meaning, depending on the column in which it is used. A circle around a letter indicates that some form of electrical short was directly associated with the particular condition noted.

c. Definitions Used in Failure Analysis:

(1) <u>End-of-charge Voltage:</u> Cell voltage at the end of charge on the failure cycle, as compared to the average of the cells remaining in that pack. A cell voltage which differs by more than about 0.05 volt from the average of the remaining cells will be listed as high (H), or low (L), unless the cell was completely shorted (S) or open-circuited (O). Voltages not substantially different are indicated as normal (N). It will be seen that in a high percentage of examples the end-of-charge voltage seems to bear little relation

to the results of the failure analysis and in many cases appears contradictory. Some of these may be due to the cells being stored for up to several weeks between the time of failure and the time of analysis (while waiting for the manufacturer to assist); others may be related to the difficulty of examining the cells without affecting the internal configuration of the cell components.

(2) Weight Loss: The weight loss in grams between the weight at the time of acceptance and that at the time of failure. Gains or losses of less than one gram are not considered (slight gains may occur from traces of solder left on the cell terminals).

(3) Deposits: Carbonate deposits, at a point of leakage such as at a terminal (T) or seam (S). Deposits may or may not be accompanied by a weight loss as defined above. Deposits are not removed prior to weighing.

(4) High Pressure: Signified by a bulged cell case (B) or by a hissing of escaped gas when cell is opened (G). It may not be present at the time the cell is opened although the bulge indicates its presence at some earlier time.

(5) Concave Sides: Refers to rectangular cells only. The sides of the can are made permanently concave by the higher pressure of neighboring cells in the pack (X). This sometimes causes a short between the case and internal elements ( ⊗ ).

(6) Weak Weld: An inadequate weld, as determined by the mechanical strength of the bond. The pieces separate, without tearing of the metal, when pulled apart by the fingers. This may be at a tab-to-plate connection (P), a tab-to-cell case connection (C), or a tab-to-terminal connection (T).

(7) Loosened Active Material: Positive plate active material which separates from the grid (+), when the plates are unrolled for failure analysis, and may come off in large, intact pieces. This condition is not noticed on flat plates, which are not flexed in the analysis.

(8) Extraneous Active Material: Pieces of loose active material found pressed between the plates (X). These are thought to have crumbled off the plate edges when the cell was being assembled, since there are no holes or bare spots on the plate itself. These pieces put pressure on the separator material and often cause a short circuit between the plates at that point ( ⊗ ).

(9) Pierced Separator: Refers only to short circuits between plates, when caused by either a grid wire ( Ⓦ ) or a tab at the tab-to-plate connection ( Ⓣ ) piercing the separator and contacting the adjacent plate.

(10) Excess Scoring: Refers to the Sonotone 5.0 a.h. cells only. The two indentations which encircle the cell case put increased pressure on the outside layer of the plates and separators at these points. Usually this results only in increased migration of negative active material, but in some cases the scoring is deep enough to damage the wrap, plate, or separator just beneath the scoring marks (X). It may result in a short circuit between the case and the adjacent plate ( Ⓧ ).

(11) Burned Positive Tab: Refers to G.E. 3.0 a.h. cells only. The positive tab, above the plates, is burned (X) and sometimes broken (b). The broken tab may fall against the case and cause a short circuit ( ⓑ ). In all cases the tape with which the positive tab had been wrapped was also burned. At times the corrosion is such that the tab crumbles when the cell is opened, so that its prior configuration cannot be determined. The burned positive tab has been attributed to an insufficient area of welding between the tab and the positive terminal, causing a high-resistance contact. However, with two exceptions, this condition was found only among cells tested at 50°-40° C temperature where it was the predominant mode of failure. This suggests that additional factors are involved.

(12) Short Separator: Related to the burned positive tab of the G.E. 3.0 a.h. cells. The separator material just below the burned tab has pulled back, apparently from the heat generated, so that the plates are exposed (X). Usually a short between adjacent plates results ( Ⓧ ).

(13) Ceramic Short: Refers to Gulton cells only. It is a dark colored, conducting deposit which causes an electrical short across the ceramic insulator at the terminal, and is a result of the silver brazing used in the cells' manufacture. It is determined by measuring the resistance between the insulated terminal and the cell case after the plates have been cut off the buses. Its presence is fairly well defined, the measured resistance being on the order of 20 ohms or less ( Ⓧ ).

(14) Migration: Active material deposited on the surface of the separator, appearing as a uniform dark coating on the separator material (X). In small areas the plate material may penetrate completely through the separator (P) and be visible as small, dark spots on the positive plate side, usually resulting in a high-resistance short circuit. Where this condition is more pronounced

there are burned spots on the separator at the point of penetration (Ⓟ). Migration is always by the negative plate material except in two very advanced cases, where there was also slight migration from the positive plate (+). Migration is accelerated at points of localized pressure on the separator, especially around the edge of the pressure area. For example in the round cells, where a pressure area is produced by a piece of tape covering the tab-to-plate connection, there is no migration at the taped area but a very dark line of migrated material outlines the tape's location. In addition, there may be brownish spots of discoloration around the edge of the tape (Ⓣ), and usually a small hole in the center of each spot. A similar situation, due to the scoring of the Sonotone 5.0 ah cell case, also occurs (Ⓢ).

(15) Blisters: Raised areas of active material, which have pulled away from the grid (+). Typically, they ranged from pinhead size to 3/8 inch in diameter, and were invariably found on the positive plates. While blistering has not been shown to have a direct bearing on cell failures, it is included here because it was common in some cell types, but rare or absent in others, and because in at least two cases the separator was burned slightly where blisters had compressed the separator material (⊕).

(16) Separator Deterioration: Decomposition of the separator material, exclusive of visible burned spots. Deteriorated separator material, as defined here, is decidedly thinner than normal, adheres to the negative plate, and has lost virtually all tensile strength (X). Shorts between the plates may result (Ⓧ). In some of the round cells this condition may be absent at the outermost portion of the separator, but become progressively worse toward the center of the core (C). Shorts between the plates may result at the center of the core (Ⓒ).

4. Discussion of Failures:

a. General Observations:

(1) Most of the cell failures occurred at the higher ambient temperatures. Of the 313 failures; 50 were at 0° C, 125 at 25° C and 138 at 50°-40° C. The relatively small number of failures at 0° C is more pronounced on certain individual cell types. For example, of the total of 48 failures of G.E. 3.0 ah cells, only four were at 0° C.

(2) In general, for a given cell type and temperature, failures occurred earliest at the greater depth of discharge, although there were exceptions. The 1.5-hour orbit was likewise more severe than the 3-hour orbit.

(3) The comparisons noted above are shown in Figures 3(A) through 3(G) and in the summary below.

| Temperature | 0° C | | | | 25° C | | | | 40° C | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Orbit Period | 1.5-Hr | | 3-Hr | | 1.5-Hr | | 3-Hr | | 1.5-Hr | | 3-Hr | |
| Percent Depth of Discharge | 15 | 25 | 15 | 25 | 25 | 40 | 25 | 40 | 15 | 25 | 15 | 25 |
| G.E. 3.0 ah | 2 | -- | 1 | 1 | 6 | 6 | 1 | 6 | 6 | 7 | 6 | 6 |
| G.E. 12 ah | -- | 1 | -- | -- | 3 | 3 | -- | 3 | 3 | 3 | 2 | 3 |
| Gould 3.5 ah | 1 | 6 | -- | -- | 7 | 6 | 6 | 7 | 6 | 10 | 7 | 6 |
| Gould 20 ah | 1 | 3 | -- | 1 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| Gulton 6.0 ah | 6 | 4 | 4 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 |
| Gulton 20 ah | 3 | 3 | 1 | 1 | 3 | 5 | 3 | 4 | 3 | 3 | 3 | 4 |
| Sonotone 5 ah | 2 | 3 | -- | -- | 6 | 6 | 2 | 6 | 6 | 6 | 6 | 6 |
| TOTALS | 15 | 20 | 6 | 9 | 34 | 35 | 21 | 35 | 33 | 38 | 33 | 34 |

(4) Many of the cell failures may be considered premature. That is, the failure appeared to result from a defect in manufacture or design. This is in contrast to an end-of-life failure, in which a basic component, such as a separator, has reached the end of its normal life span at the particular cycling conditions. Some examples of premature failures are those due to leakage, pierced separator, burned tab, ceramic short, or extraneous active material.

(5) It is frequently difficult to isolate the exact cause of failure for a particular cell. In some cases several factors may have been responsible. In others, it is not obvious why the conditions found should have resulted in failure. For this reason, unless otherwise stated, this report will not attempt to isolate the direct cause of failure; the conditions noted in Tables Va through Vg and in the discussions are included because they are abnormalities and because they may have contributed to the cell failure.

(6) By direction of the Goddard Space Flight Center cell failure analysis shall be performed at NAD Crane. The manufacturer is invited to participate as an observer in all cases of failure analysis of his cells.

b. Discussion of Failures by Cell Type:

(1) General Electric:

(a) 3.0 ah Cells: There were 48 cell failures, of which four were at 0° C, 19 were at 25° C, and 25 were at the 50°-40° C ambient temperature (one at 50° C before dropping temperature to 40° C). The findings of the failure analyses for these cells are shown in Table Va.

1. Migration was present at all test conditions except 25 percent depth of discharge, 40° C and 1.5-hour orbit period. This was probably because of the short life of these cells; only 157 days of cycling. Separator deterioration began to appear in failures that occurred after 287 days of cycling. Blistering on the positive plates was very common at 25° C after 436 days of cycling, while burned tabs, along with short separator, occurred at 40° C in the early failures.

(b) 12 ah Cells: There were 21 failures, of which one was at 0° C, nine were at 25° C and 11 were at 50°-40° C. The findings of the failure analyses for these cells are shown in Table Vb.

1. Migration was present in most of the cell failures that occurred after 239 days of cycling. Cell failures began to show signs of separator deterioration after 240 days of cycling. High internal pressures occurred in a few cell failures at all ambient temperatures.

(2) Gould:

(a) 3.5 ah Cells: There were 62 cell failures, of which seven were at 0° C, 26 were at 25° C and 29 were at 50°-40° C ambient temperature (three at 50° C before dropping temperature to 40° C). The findings of the failure analyses for these cells are shown in Table Vc.

1. Weight loss was one of the main conditions found in these failures. Losses ranged from 1.0 gram to 7.1 grams. Deposits were always present with the weight loss which occurred earlier at 25° C and 40° C but did not appear in the cell failures at 0° C until after 687 days of cycling. Migration and separator deterioration were present at all conditions. Weak welds were more frequent at 40° C with a few at 25° C and only one at 0° C.

(b) 20 ah Cells: There were 29 cell failures, of which five were at 0° C, 12 were at 25° C and 12 were at 50°-40° C ambient temperature (one at 50° C before dropping

temperature to 40° C). The findings of the failure analyses for these cells are shown in Table Vd.

1. High internal pressure was present in almost all failures. Pierced separator was more predominant at the 1.5-hour orbit period at all ambient temperatures. Blisters were present on the positive plates at 25° C for the 3-hour orbit period and the 1.5-hour and 3-hour orbit periods at 40° C.

(3) Gulton:

(a) 6.0 ah Cells: There were 68 cell failures, of which 20 were at 0° C, 24 were at 25° C and 24 were at 50°-40° C ambient temperature (four at 50° C before dropping temperature to 40° C). The findings of the failure analyses for these cell failures are shown in Table Ve.

1. Ceramic shorts were the most common mode of failure. Weight losses were also very common and ranged from 1.0 gram to 12.0 grams. Most of the cells that lost weight did not show signs of leakage in the form of deposits around the seals. Most of the failures due to ceramic short did not show signs of migration or separator deterioration because the failures occurred early in life.

(b) 20 ah Cells: There were 36 cell failures, of which eight were at 0° C, 15 were at 25° C and 13 were at 50°-40° C ambient temperature. The findings of the failure analyses for these cell failures are shown in Table Vf.

1. Weight losses were very common at 0° C and 25° C and ranged from 6.8 grams to 26.9 grams. Most of the cells that lost weight did not show signs of leakage in the form of deposits around the seals. Several cell failures were caused by the sides of the case being pushed against the buses at the top of the plates. Migration and separator deterioration were found at 40° C but not very common at 0° C or 25° C.

(4) Sonotone:

(a) 5.0 ah Cells: There were 49 cell failures, of which five were at 0° C, 20 were at 25° C and 24 were at 50°-40° C ambient temperature. The findings of the failure analyses for these cells are shown in Table Vg.

1. Excess scoring, along with migration, was present in most of the cell failures at all ambient temperatures. Separator deterioration was more frequent at 25° C and 40° C. High internal pressure and leakage as shown by deposits around the seal were present at 25° C and 40° C.

## LIST OF SYMBOLS USED IN TABLES Va THROUGH Vg

End-of-charge Voltage:
- H - High
- L - Low
- S - Shorted
- O - Open Circuited
- N - Normal

Deposits:
- T - Terminal
- S - Seam

High Pressure:
- B - Bulged
- G - Gas Present

Concave Sides:
- X - Present
- (X) - Caused Short

Weak Weld:
- P - Tab to Plate
- C - Tab to Case
- T - Tab to Terminal

Loosened Active Material:
- + - Present

Extraneous Active Material:
- X - Present
- (X) - Caused Short

Pierced Separator:
- (W) - Grid Wire Short
- (T) - Tab to Plate Short

Excess Scoring:
- X - Present
- (X) - Caused Short

Burned Positive Tab:
- b - Broken
- (b) - Caused Short

Short Separator:
- X - Present
- (X) - Caused Short

Ceramic Short:
- (X) - Present

Migration:
- X - General
- P - Small Area Penetration
- (P) - Shorting Penetration
- \+ - Positive Plate
- (T) - Shorting Around Tab
- (S) - Shorting Around Scoring

Blisters:
- + - Present
- (+) - Caused Short

Separator Deterioration:
- X - General
- (X) - Permitted Shorting
- C - Center of Core
- (C) - Permitted Shorting

TABLE Va

G.E. 3.0 ah CELLS. DATA ON CELL FAILURES THROUGH 17 DECEMBER 1967

| Depth of Discharge | Pack Number | Cell Position in Pack | Cell Serial Number | Cycles Completed | Days of Cycling Completed | End-of-charge Voltage | Weight Loss (grams) | Deposits | Migration | Blisters | Loosened Active Material | Extraneous Active Material | Burned Positive Tab | Short Separator | Separator Deterioration | Additional Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0° C; 1.5-hour orbit | | | | | | | | | | | |
| 15% | 63A | 6 | 245 | 14917 | 932 | N | | | ⊗ | + | + | | | | X | |
| 15% | 63A | 4 | 169 | 20126 | 1258 | H | 1.4 | T | X | | | | ⓑ | | X | |
| | | | | | 0° C; 3-hour orbit | | | | | | | | | | | |
| 25% | 68A | 2 | 714 | 7054 | 882 | L | | | X | | | | | | X | |
| 15% | 67A | 3 | 498 | 9980 | 1248 | L | | T | X | | | | ⓑ | | X | |
| | | | | | 25° C; 1.5-hour orbit | | | | | | | | | | | |
| 40% | 16A | 7 | 427 | 3285 | 249 | N | | | | | | | ⓑ | | | |
| 40% | 16A | 6 | 58 | 4473 | 280 | N | | | P | | | | | | | 1 |
| 40% | 16A | 1 | 361 | 4741 | 296 | N | | | P | | | | | | | |
| 40% | 16A | 5 | 522 | 4917 | 307 | L | | | P | | | | | | | |
| 40% | 16A | 10 | 456 | 4917 | 307 | L | | | P | | | | | | | |
| 40% | 16A | 4 | 719 | 5013 | 313 | L | | | Ⓟ | | | | | | | |
| 25% | 15A | 7 | 432 | 8065 | 504 | L | | | X | + | | | | | X | |
| 25% | 15A | 8 | 414 | 8254 | 516 | L | | | X | + | | | | | X | |
| 25% | 15A | 5 | 479 | 8714 | 545 | N | | T | X | + | | | | | X | |
| 25% | 15A | 10 | 267 | 10123 | 633 | N | | | Ⓟ | | | | | | X | |
| 25% | 15A | 4 | 485 | 10382 | 649 | L | | | Ⓟ | + | | | | | X | |
| 25% | 15A | 9 | 447 | 10382 | 649 | L | | | Ⓟ | + | | | | | X | |
| | | | | | 25° C; [illegible]-hour orbit | | | | | | | | | | | |
| 40% | 20A | 5 | 421 | 3704 | 463 | L | | | X | + | | | | | X | |
| 40% | 20A | 2 | 433 | 4485 | 561 | L | | | Ⓟ | + | | | X | | X | |
| 40% | 20A | 6 | 711 | 4485 | 561 | L | | T | Ⓟ | + | | | | | X | |
| 40% | 20A | 3 | 710 | 4889 | 611 | S | | T | Ⓟ | + | | | | | X | |
| 40% | 20A | 4 | 415 | 5410 | 676 | N | | T | X | + | | | | | Ⓧ | |
| 40% | 20A | 9 | 721 | 5410 | 676 | L | | | X | + | | | | | Ⓧ | |
| 25% | 19A | 1 | 551 | 8572 | 1072 | N | | T | X | | | | ⓑ | | X | |

* Additional Notes:
1. Short circuit between plates, no obvious cause.

TABLE Va (Contd)

G.E. 3.0 ah CELLS. DATA ON CELL FAILURES THROUGH 17 DECEMBER 1967

| Depth of Discharge | Pack Number | Cell Position in Pack | Cell Serial Number | Cycles Completed | Days of Cycling Completed | End-of-charge Voltage | Weight Loss (grams) | Deposits | Migration | Blisters | Loosened Active Material | Extraneous Active Material | Burned Positive Tab | Short Separator | Separator Deterioration | Additional Notes* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 50°-40° C; 1.5-hour orbit | | | | | | | | | | | | | | | | |
| 15% | 39A | 2 | 541 | 779 | 49 | H | | T | | | | | X | ⊗ | | 1 |
| 25% | 40A | 3 | 464 | 2073 | 130 | H | | | | | | | X | ⊗ | | |
| 15% | 39A | 6 | 540 | 2083 | 130 | H | | T | | | | | X | ⊗ | | |
| 25% | 40A | 7 | 47 | 2182 | 136 | H | | | | | | | b | ⊗ | | |
| 25% | 40A | 8 | 3131 | 2182 | 136 | N | | T | | | + | | | | | |
| 25% | 40A | 5 | 49 | 2446 | 153 | H | | | | | | X | X | | | |
| 25% | 40A | 10 | 45 | 2461 | 154 | H | | | | | | X | | | | |
| 25% | 40A | 2 | 466 | 2509 | 157 | H | | T | | | | | X | | | 2 |
| 25% | 40A | 6 | 441 | 2509 | 157 | L | | | | | | | X | ⊗ | | |
| 15% | 39A | 7 | 549 | 2532 | 158 | H | | | | | | | X | | | |
| 15% | 39A | 1 | 527 | 7213 | 451 | N | | T | X | | | | X | | X | |
| 15% | 39A | 5 | 534 | 8109 | 507 | N | 3.5 | | X | | | | X | | X | |
| 15% | 39A | 8 | 550 | 8109 | 507 | N | | | P | | | | | | X | |
| 50°-40° C; 3-hour orbit | | | | | | | | | | | | | | | | |
| 15% | 43A | 4 | 416 | 1182 | 148 | L | | | | | | | X | ⊗ | | |
| 15% | 43A | 3 | 499 | 1515 | 189 | H | | | | | | | b | ⊗ | | |
| 25% | 44A | 6 | 222 | 1672 | 209 | O | | | | | | | X | | | |
| 15% | 43A | 6 | 412 | 1911 | 239 | O | | | | | | | b | | | |
| 15% | 43A | 9 | 426 | 2298 | 287 | O | | | P | | | | b | X | X | |
| 15% | 43A | 7 | 436 | 2515 | 314 | O | | | | | | | b | | X | 3 |
| 15% | 43A | 10 | 435 | 2656 | 332 | O | | | P | | | | b | | X | |
| 25% | 44A | 8 | 366 | 3848 | 481 | H | | | P | + | | | | | X | |
| 25% | 44A | 1 | 459 | 3854 | 482 | S | | T | P | | | | | | X | |
| 25% | 44A | 3 | 77 | 3854 | 482 | N | | | X | | | | | | X | |
| 25% | 44A | 2 | 3120 | 4487 | 561 | H | | T | P | + | + | | | | X | |
| 25% | 44A | 10 | 296 | 4487 | 561 | L | | T | Ⓟ | | + | | | | X | |

* Additional Notes:

1. Failed while pack was cycling at 50° C.
2. Tabs were found shorted together when cell was opened.
3. Short circuit between plates due to improper separator placement.

TABLE Vb

G.E. 12 ah CELLS. DATA ON CELL FAILURES THROUGH 17 DECEMBER 1967

| Depth of Discharge | Pack Number | Cell Position in Pack | Cell Serial Number | Cycles Completed | Days of Cycling Completed | End-of-charge Voltage | Deposits | High Pressure | Migration | Blisters | Separator Deterioration | Pierced Separator | Additional Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 0° C; 1.5-hour orbit | | | | | | | | | | |
| 2% | 124A | 3 | 417 | 13218 | 826 | H | T | B | (P) | | X | | 1 |
| | | | 0° C; 3-hour orbit (No Failures) | | | | | | | | | | |
| | | | 25° C; 1.5-hour orbit | | | | | | | | | | |
| 40% | 96A | 3 | 445 | 3822 | 239 | L | | | (P) | | | | |
| 40% | 96A | 2 | 446 | 4020 | 251 | L | | | (P) | | | | |
| 40% | 96A | 4 | 442 | 4020 | 251 | L | | | (P) | | | | |
| 25% | 82A | 2 | 430 | 7527 | 470 | N | | | X | | X | (W) | |
| 25% | 82A | 5 | 397 | 10624 | 664 | N | | | (P) | | X | | |
| 25% | 82A | 1 | 437 | 10878 | 680 | N | T | | (P) | | X | | |
| | | | 25° C; 3-hour orbit | | | | | | | | | | |
| 40% | 97A | 2 | 438 | 3894 | 487 | L | T | | P | | X | | |
| 40% | 97A | 3 | 435 | 3946 | 493 | N | | G | X | + | X | | |
| 40% | 97A | 4 | 434 | 5002 | 625 | N | | G | X | | X | | |
| | | | 50°-40° C; 1.5-hour orbit | | | | | | | | | | |
| 25% | 99A | 3 | 429 | 3841 | 240 | L | T | | P | | | | |
| 25% | 99A | 2 | 432 | 3841 | 240 | L | | | X | | X | | |
| 25% | 99A | 1 | 440 | 4835 | 303 | L | | | X | | X | | |
| 15% | 85A | 4 | 428 | 8888 | 556 | L | | B | X | | X | | |
| 15% | 85A | 3 | 448 | 8947 | 559 | L | | B | X | | X | | |
| 15% | 85A | 2 | 455 | 9710 | 607 | N | | G | X | | X | | |
| | | | 50°-40° C; 3-hour orbit | | | | | | | | | | |
| 25% | 100A | 3 | 427 | 4170 | 521 | S | | B | | + | (X) | | |
| 25% | 100A | 2 | 431 | 4358 | 548 | S | | B | X | | (X) | | |
| 25% | 100A | 1 | 436 | 4424 | 553 | S | | | X | | (X) | | |
| 15% | 86A | 3 | 402 | 8988 | 1124 | L | T | B,G | (X) | | | | |
| 15% | 86A | 5 | 400 | 10575 | 1322 | L | | B,G | X | | (C) | | |

* Additional Notes:
1. Lost 8.4 grams of weight.

**TABLE Vc**

GOULD 3.5 ah CELLS. DATA ON CELL FAILURES THORUGH 17 DECEMBER 1967

| Depth of Discharge | Pack Number | Cell Position in Pack | Cell Serial Number | Cycles Completed | Days of Cycling Completed | End-of-charge Voltage | Weight Loss (grams) | Deposits | High Pressure | Pierced Separator | Migration | Blisters | Loosened Active Material | Extraneous Active Material | Weak Weld | Separator Deterioration | Additional Notes* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0° C; 1.5-hour orbit | | | | | | | | | | | | | | | | | |
| 25% | 52A | 8 | 116 | 7858 | 491 | L | | | G | | X | | | | | X | |
| 25% | 52A | 10 | 194 | 8367 | 523 | N | | | G | | P,⊗ | | | | | | |
| 25% | 52A | 7 | 108 | 9724 | 608 | H | | | | | X | | + | | | X | |
| 25% | 52A | 9 | 118 | 9724 | 608 | L | | | | | X | | + | | | X | |
| 25% | 52A | 3 | 55 | 10994 | 687 | S | | T | | | X | | + | ⊗ | | X | |
| 25% | 52A | 2 | 22 | 13730 | 858 | L | | T | | | ⊗ | | | | P | X | |
| 15% | 51A | 10 | 186 | 14738 | 921 | L | 1.0 | T | | | ⊗ | | | | | ⊗ | |
| 0° C; 3-hour orbit (No Failures) | | | | | | | | | | | | | | | | | |

**TABLE Vc (Contd)**

GOULD 3.5 ah CELLS. DATA ON CELL FAILURES THROUGH 17 DECEMBER 1967

| Depth of Discharge | Pack Number | Cell Position in Pack | Cell Serial Number | Cycles Completed | Days of Cycling Completed | End-of-charge Voltage | Weight Loss (grams) | Deposits | High Pressure | Pierced Separator | Migration | Blisters | Loosened Active Material | Extraneous Active Material | Weak Weld | Separator Deterioration | Additional Notes* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 25° C; 1.5-hour orbit | | | | | | | | | | | | | | | | | |
| 40% | 4A | 7 | 81 | 1609 | 101 | L | 3.2 | T | B | | | | | | | | |
| 40% | 4A | 8 | 90 | 1827 | 114 | L | 2.7 | T | B | | | | | | | | |
| 40% | 4A | 1 | 2 | 2110 | 132 | L | | | G | | | | | | | C | |
| 25% | 3A | 5 | 73 | 2785 | 174 | H | | | | | | | | ⊗ | | | |
| 40% | 4A | 6 | 43 | 2954 | 185 | L | 1.3 | T | | | X | | | | | X | |
| 40% | 4A | 3 | 27 | 3029 | 189 | N | | T | | | | | | | | X | |
| 25% | 3A | 2 | 54 | 3090 | 193 | L | 1.7 | T | | | | | | | P | | |
| 40% | 4A | 10 | 198 | 3164 | 198 | L | 1.6 | T | | | | | | X | | X | |
| 25% | 3A | 9 | 165 | 4081 | 255 | N | 1.7 | T | | ⓦ | | | | | P | | |
| 25% | 3A | 6 | 93 | 4289 | 268 | N | 2.6 | T | | | X | | | | | X | |
| 25% | 3A | 7 | 97 | 4401 | 275 | N | 2.5 | T | | | X | | | | | X | |
| 25% | 3A | 4 | 77 | 4751 | 297 | N | | | | | X | + | | | | X | |
| 25% | 3A | 10 | 188 | 4751 | 297 | N | 2.1 | T | | | X | | | | | | |
| 25° C; 3-hour orbit | | | | | | | | | | | | | | | | | |
| 40% | 8A | 6 | 68 | 1346 | 168 | L | 1.5 | T | | | X | | | | | | |
| 40% | 8A | 8 | 112 | 1704 | 213 | N | 2.0 | T | | | | | | | P,C | | |
| 40% | 8A | 1 | 39 | 1985 | 248 | N | | T | | | X | | | | | X | |
| 40% | 8A | 10 | 170 | 1985 | 248 | N | 1.8 | T | | | | | | | P | C | |
| 40% | 8A | 7 | 78 | 2138 | 267 | L | 1.4 | T | | | X | | | | C | X | |
| 40% | 8A | 2 | 41 | 2494 | 312 | L | 1.7 | T | | | X | | | | P | X | |
| 40% | 8A | 9 | 130 | 2494 | 312 | L | 2.1 | T | | | + | | | | | X | |
| 25% | 7A | 2 | 49 | 3007 | 376 | L | 2.7 | T | | | X | | | | P | X | |
| 25% | 7A | 1 | 37 | 3130 | 391 | N | 1.1 | T | | | P | | + | | P | X | 1 |
| 25% | 7A | 6 | 109 | 3483 | 435 | L | 2.0 | T | | | P | | | | P | X | |
| 25% | 7A | 5 | 104 | 3736 | 467 | S | 1.1 | T | | | P | | | | P | X | |
| 25% | 7A | 7 | 131 | 3884 | 486 | N | 1.7 | T | | | P | | + | | | X | |
| 25% | 7A | 3 | 62 | 4173 | 522 | N | 1.4 | T | | | P | | | | P | X | |

* Additional Notes:
1. Glass seal broken.

TABLE Ve (Contd)

GOULD 3.5 ah CELLS. DATA ON CELL FAILURES THROUGH 17 DECEMBER 1967

| Depth of Discharge | Pack Number | Cell Position in Pack | Cell Serial Number | Cycles Completed | Days of Cycling Completed | End-of-charge Voltage | Weight Loss (grams) | Deposits | High Pressure | Pierced Separator | Migration | Blisters | Loosened Active Material | Extraneous Active Material | Weak Weld | Separator Deterioration | Additional Notes* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 50°-40° C; 1.5-hour orbit | | | | | | | | | | | | | | | | | |
| 25% | 28A | 2 | 122 | 408 | 26 | N | 1.8 | T | | | | | | | C | | 1 |
| 25% | 28A | 7 | 157 | 484 | 30 | N | 2.0 | T | B | | | | | | | | |
| 25% | 28A | 8 | 158 | 484 | 30 | N | 1.9 | T | B | | | | | | | | |
| 25% | 28A | 5 | 141 | 360 | 54 | H | 3.5 | T | | | | | | | | | |
| 25% | 28A | 10 | 168 | 1293 | 81 | H | | | | | | | | | C | | |
| 25% | 28A | 1 | 121 | 1811 | 113 | L | | | | W | | | | | | | |
| 25% | 28A | 3 | 133 | 1811 | 113 | H | | | | | | | | | C | | |
| 25% | 28A | 4 | 140 | 1811 | 113 | L | | | | | P | + | | | | | |
| 25% | 28A | 6 | 155 | 1811 | 113 | L | | | | | P | | | | C | | |
| 25% | 28A | 9 | 163 | 1811 | 113 | L | | T | | | P | | | | C | | |
| 15% | 27A | 3 | 13 | 2901 | 181 | L | 1.5 | T | | | | | + | | | X | |
| 15% | 27A | 8 | 195 | 2901 | 181 | N | 3.6 | T | | | | | + | | | C | |
| 15% | 27A | 7 | 103 | 2998 | 187 | N | | | B | | | | | X | | | |
| 15% | 27A | 10 | 200 | 3270 | 204 | N | 2.5 | T | | | P | | | | C | C | |
| 15% | 27A | 9 | 197 | 4102 | 256 | H | 1.4 | T | | | P | | | | | X | |
| 15% | 27A | 2 | 11 | 4435 | 280 | N | | T | | | X | | | | | X | |
| 50°-40° C; 3-hour orbit | | | | | | | | | | | | | | | | | |
| 25% | 32A | 6 | 125 | 138 | 17 | N | | | | | | | | | C | | 1,2 |
| 25% | 32A | 3 | 65 | 495 | 62 | N | 1.5 | T | | | | | | | | | 1,3 |
| 25% | 32A | 1 | 1 | 800 | 100 | L | 3.2 | T | | | P | | | | | C | |
| 25% | 32A | 4 | 67 | 875 | 109 | L | 2.2 | T | | | P | | | | C | | |
| 25% | 32A | 7 | 132 | 875 | 109 | S | 4.4 | T | B | | | | | | | | 4 |
| 25% | 32A | 9 | 149 | 974 | 122 | H | 1.1 | T | | | | | | X | P,C | | |
| 15% | 31A | 9 | R166 | 1500 | 188 | L | 7.1 | T | | | | | | | | X | |
| 15% | 31A | 10 | R179 | 1500 | 188 | L | 1.5 | T | | | P | | | | P | X | |
| 15% | 31A | 2 | R92 | 1696 | 212 | H | | | | | | | | X | | X | |
| 15% | 31A | 3 | 126 | 2411 | 301 | L | 2.1 | T | | | X | | | X | P | X | |
| 15% | 31A | 8 | R162 | 2477 | 310 | H | 2.4 | T | | | P | | | | C | X | |
| 15% | 31A | 1 | 72 | 2517 | 315 | L | 1.8 | T | | | | | | X | P | X | |
| 15% | 31A | 6 | 143 | 2517 | 315 | L | | | G | | X | | | X | P,T | X | |

* Additional Notes:
1. Failed while pack was cycling at 50° C.
2. Corrosion noted on negative tab.
3. Glass at seal was broken.
4. Cell ruptured from high internal pressure while pack was shut off.

## TABLE Vd

GOULD 20 ah CELLS. DATA ON CELL FAILURES THROUGH 17 DECEMBER 1967

| Depth of Discharge | Pack Number | Cell Position in Pack | Cell Serial Number | Cycles Completed | Days of Cycling Completed | End-of-charge Voltage | High Pressure | Pierced Separator | Migration | Blisters | Loosened Active Material | Extraneous Active Material | Separator Deterioration | Additional Notes* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0° C; 1.5-hour orbit | | | | | | | | | | | | | | |
| 25% | 98A | 5 | 77 | 3556 | 222 | L | | | X | | | | X | |
| 25% | 98A | 1 | 47 | 8619 | 539 | L | B | | X | | + | | X | 1 |
| 25% | 98A | 4 | 14 | 10641 | 665 | L | B | | X | | | | ⊗ | |
| 15% | 84A | 5 | 31 | 17040 | 1065 | L | G | Ⓦ | X | | | | ⊗ | |
| 0° C; 3-hour orbit | | | | | | | | | | | | | | |
| 25% | 94A | 3 | 54 | 9110 | 1139 | N | G | | ⊗ | | | + | X | |

* Additional Notes:

1. Short trhough separator at bottom of plates where tape holds plates together.

TABLE Vd (Contd)

GOULD 20 ah CELLS. DATA ON CELL FAILURES THROUGH 17 DECEMBER 1967

| Depth of Discharge | Pack Number | Cell Position in Pack | Cell Serial Number | Cycles Completed | Days of Cycling Completed | End-of-charge Voltage | High Pressure | Pierced Separator | Migration | Blisters | Loosened Active Material | Extraneous Active Material | Separator Deterioration | Additional Notes* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 25° C; 1.5-hour orbit | | | | | | | | | | |
| 40% | 118A | 2 | 61 | 1747 | 109 | L | G | ⊗ | | | | | | |
| 40% | 118A | 4 | R91 | 1963 | 123 | L | G | ⊗ | | | | | | |
| 25% | 104A | 1 | 69 | 2672 | 167 | L | G | ⊗ | | | | | | |
| 25% | 104A | 5 | R36 | 2826 | 177 | L | G | ⊗ | | | | X | | |
| 40% | 118A | 5 | 92 | 2937 | 184 | L | G | | | | | ⊗ | | |
| 25% | 104A | 3 | 5 | 2980 | 186 | L | G | | | | | | ⊗ | |
| | | | | 25° C; 3-hour orbit | | | | | | | | | | |
| 40% | 119A | 5 | 73 | 222 | 28 | L | | | | | | | | 1 |
| 40% | 119A | 2 | 80 | 1793 | 224 | N | G | | X | + | | | | |
| 40% | 119A | 3 | 86 | 1793 | 224 | N | G | | X | + | | | | |
| 25% | 105A | 1 | 40 | 4306 | 538 | L | G | | Ⓟ | + | | | X | |
| 25% | 105A | 3 | 23 | 5580 | 698 | L | G | | X | | | | ⊗ | 2 |
| 25% | 105A | 4 | 41 | 5690 | 711 | L | G | | X | | | | X | 3 |
| | | | | 50°-40° C; 1.5-hour orbit | | | | | | | | | | |
| 25% | 126A | 3 | 9 | 1273 | 80 | L | G | Ⓦ | | | | | | 4 |
| 25% | 126A | 4 | R29 | 1509 | 94 | L | G | Ⓦ | | + | | | X | |
| 25% | 126A | 5 | 11 | 1569 | 98 | L | G | Ⓦ | | | | | | |
| 15% | 112A | 1 | 17 | 5005 | 313 | L | G | | | | | | ⊗ | |
| 15% | 112A | 2 | 25 | 5005 | 313 | L | G | | | | | | ⊗ | |
| 15% | 112A | 5 | 38 | 5213 | 326 | L | | Ⓤ | | + | | | ⊗ | |
| | | | | 50°-40° C; 3-hour orbit | | | | | | | | | | |
| 25% | 122A | 2 | 16 | 801 | 100 | L | G | | X | + | | | X | |
| 25% | 122A | 3 | 58 | 801 | 100 | L | G | | X | + | | | X | |
| 25% | 122A | 5 | 18 | 983 | 123 | L | G | | X | + | | | | |
| 15% | 108A | 4 | R99 | 3796 | 475 | L | | | Ⓟ | | | | X | |
| 15% | 108A | 2 | 81 | 4003 | 500 | S | G | | | + | | | X | 5 |
| 15% | 108A | 3 | 82 | 4233 | 529 | S | G | Ⓤ | X | + | + | | X | |

* Additional Notes:

1. Short circuit between plates, near edge, no obvious cause.
2. Deposit around positive terminal.
3. Weak weld tab to terminal.
4. Failed while pack was cycling at 50° C.
5. Several shorts caused by small pieces of metal between plates.

TABLE Ve

GULTON 6.0 ah CELLS. DATA ON CELL FAILURES THROUGH 17 DECEMBER 1967

| Depth of Discharge | Pack Number | Cell Position in Pack | Cell Serial Number | Cycles Completed | Days of Cycling Completed | End-of-charge Voltage | Weight Loss (grams) | Deposits | High Pressure | Concave Sides | Pierced Separator | Ceramic Short* | Migration | Blisters | Separator Deterioration | Additional Notes* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0° C; 1.5-hour orbit | | | | | | | | | | | | | | | | |
| 15% | 61A | 5 | 2307 | 2762 | 173 | L | | | | | | ⊗ | | | | |
| 25% | 62A | 10 | 1630 | 2295 | 187 | H | 6.8 | T | B | | | | | + | | 1 |
| 25% | 62A | 4 | 1722 | 4066 | 254 | L | | | | | ⊕ | | | + | X | |
| 15% | 61A | 4 | 1825 | 4024 | 256 | L | | | B | | | ⊗ | X | + | | |
| 15% | 61A | 10 | 2311 | 4285 | 268 | L | | | B | | | ⊗ | X | + | | |
| 15% | 61A | 6 | 2400 | 4413 | 276 | L | | | B | | | ⊗ | | + | | |
| 25% | 62A | 5 | 1806 | 4441 | 278 | L | | | B | | | ⊗ | | + | | |
| 25% | 62A | 7 | 2227 | 8520 | 537 | L | | | B | | | ⊗ | X | + | | |
| 15% | 61A | 3 | 2636 | 9760 | 610 | L | 8.7 | | B | X | | ⊗ | X | + | X | 2 |
| 15% | 61A | 1 | 1616 | 10146 | 634 | H | 6.0 | T | | ⊗ | | | X | | X | |
| 0° C; 3-hour orbit | | | | | | | | | | | | | | | | |
| 25% | 66A | 6 | 1794 | 1045 | 131 | H | 5.1 | | B | ⊗ | | | | | | 1 |
| 25% | 66A | 8 | 1843 | 1173 | 147 | L | | | | X | | ⊗ | | | | |
| 25% | 66A | 5 | 1781 | 1237 | 155 | H | | T | B | | | | | ⊕ | | 1 |
| 25% | 66A | 3 | 1634 | 1417 | 177 | N | 2.3 | | B | X | | ⊗ | | + | | |
| 25% | 66A | 7 | 1823 | 2122 | 265 | L | 7.8 | T | B | X | | | X | + | | |
| 25% | 66A | 4 | 1591 | 4414 | 552 | N | | T | B | ⊗ | | ⊗ | P | | | |
| 15% | 65A | 4 | 1284 | 5012 | 626 | L | | T | G | X | ⊕ | | X | + | | |
| 15% | 65A | 6 | 2025 | 5706 | 713 | L | | | | ⊗ | | | P | + | X | |
| 15% | 65A | 8 | 1808 | 6186 | 713 | L | | | | ⊗ | | | P | + | ⊗ | |
| 15% | 65A | 5 | 2303 | 9431 | 1179 | L | | | | ⊗ | | | P | + | ⊗ | |

* Additional Notes:

1. Broken ceramic at seal.
2. Rough place on positive plate shorted through separator.

**TABLE Ve (Contd)**

GULTON 6.0 ah CELLS. DATA ON CELL FAILURES THROUGH 17 DECEMBER 1967

| Depth of Discharge | Pack Number | Cell Position in Pack | Cell Serial Number | Cycles Completed | Days of Cycling Completed | End-of-charge Voltage | Weight Loss (grams) | Deposits | High Pressure | Concave Sides | Pierced Separator | Ceramic Short | Migration | Blisters | Separator Deterioration | Additional Notes* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 25° C; 1.5-hour orbit | | | | | | | | | | | |
| 40% | 14A | 4 | 1623 | 262 | 16 | H | 12.0 | | B | | | | | | | |
| 40% | 14A | 5 | 1635 | 262 | 16 | L | 6.0 | T | B | X | | | | | | 1 |
| 25% | 13A | 1 | 2305 | 308 | 19 | H | 12.0 | T | B | | | | | | | |
| 40% | 14A | 1 | 2356 | 450 | 28 | H | 12.0 | | B | | | | | | | |
| 25% | 13A | 10 | 2355 | 502 | 31 | H | 10.0 | | B | | | | | | | |
| 40% | 14A | 2 | 2387 | 1113 | 70 | H | | | | | | ⊗ | | | | |
| 40% | 14A | 3 | 2391 | 1618 | 101 | L | | | | | | ⊗ | | | | |
| 40% | 14A | 7 | 3208 | 2086 | 130 | N | | | | | | ⊗ | | | | |
| 25% | 13A | 5 | 3134 | 2969 | 186 | L | | | | | | ⊗ | | + | | |
| 25% | 13A | 7 | 3211 | 3084 | 193 | L | | | | | | ⊗ | | + | | |
| 25% | 13A | 4 | 2613 | 3598 | 225 | L | | | | | | ⊗ | | + | X | |
| 25% | 13A | 2 | 2324 | 4021 | 251 | L | | | B | | | ⊗ | X | + | X | |
| | | | | | 25° C; 3-hour orbit | | | | | | | | | | | |
| 40% | 18A | 6 | 1826 | 365 | 46 | N | 3.0 | | | X | | ⊗ | | | | |
| 40% | 18A | 3 | 1615 | 608 | 76 | N | 5.1 | T | B | | | | | | | |
| 40% | 18A | 7 | 1827 | 643 | 80 | H | | | B | | | ⊗ | | | | |
| 40% | 18A | 9 | 2228 | 643 | 80 | H | | | | | | ⊗ | | | | |
| 25% | 17A | 3 | 1832 | 721 | 90 | H | | | B | | | ⊗ | | | ⊗ | |
| 25% | 17A | 5 | 1862 | 721 | 90 | H | | | | | | ⊗ | | | | |
| 40% | 18A | 5 | 1562 | 1145 | 143 | L | | | | | | ⊗ | | | | |
| 40% | 18A | 1 | 1233 | 1550 | 194 | L | | | | | | ⊗ | | + | | |
| 25% | 17A | 10 | 2348 | 1698 | 211 | I | | | | | | ⊗ | X | + | | |
| 25% | 17A | 1 | 1757 | 2375 | 297 | L | | | | | | ⊗ | | | | |
| 25% | 17A | 2 | 1598 | 2442 | 306 | L | | | | | | ⊗ | P | + | | |
| 25% | 17A | 9 | 2347 | 2885 | 361 | L | | | B | | | ⊗ | | + | | |

* Additional Notes:
1. Broken ceramic at seal.

**TABLE Ve (Contd)**

GULTON 6.0 ah CELLS. DATA ON CELL FAILURES THROUGH 17 DECEMBER 1967

| Depth of Discharge | Pack Number | Cell Position in Pack | Cell Serial Number | Cycles Completed | Days of Cycling Completed | End-of-charge Voltage | Weight Loss (grams) | Deposits | High Pressure | Concave Sides | Pierced Separator | Ceramic Short | Migration | Blisters | Separator Deterioration | Additional Notes* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 50°-40° C; 1.5-hour orbit | | | | | | | | | | | | | | | | |
| 25% | 38A | 8 | 1454 | 37 | 2 | S | | | | | | ⊗ | | | | 1 |
| 25% | 38A | 6 | 1815 | 114 | 7 | L | 3.5 | | | | | ⊗ | | | | 1 |
| 25% | 38A | 9 | 1853 | 187 | 12 | N | 4.0 | T | | | | ⊗ | | | | |
| 25% | 38A | 3 | 1627 | 225 | 14 | H | 3.5 | | | | | | | | | 2 |
| 15% | 37A | 3 | 1764 | 238 | 15 | L | 4.0 | | | | | ⊗ | | | | 1 |
| 25% | 38A | 5 | 2405 | 1333 | 83 | N | | | | ⊗ | | | | | | |
| 25% | 38A | 2 | 1626 | 1377 | 86 | L | | | B | | | ⊗ | | | | |
| 15% | 37A | 8 | 1784 | 1566 | 98 | L | 10.5 | | | | | ⊗ | | | | |
| 15% | 37A | 4 | 1802 | 2819 | 176 | L | | | | | | ⊗ | | + | | |
| 15% | 37A | 10 | 2333 | 2981 | 186 | N | | | | | | ⊗ | | + | | |
| 15% | 37A | 7 | 1769 | 4897 | 306 | N | 1.0 | | | | | ⊗ | | + | X | |
| 15% | 37A | 6 | 1814 | 6064 | 379 | H | | T | | | | ⊗ | X | + | X | |
| 50°-40° C; 3-hour orbit | | | | | | | | | | | | | | | | |
| 25% | 42A | 8 | 2309 | 96 | 12 | N | | | | | | ⊗ | | | | |
| 25% | 42A | 7 | 2346 | 382 | 48 | L | | S | | | | | | | | |
| 25% | 42A | 9 | 2306 | 416 | 52 | H | | | | | | ⊗ | | | | |
| 25% | 42A | 1 | 918 | 484 | 61 | L | 3.1 | S | B | | | ⊗ | | | | |
| 15% | 41A | 9 | 1771 | 649 | 81 | H | | | | | | ⊗ | | | | |
| 15% | 41A | 6 | 1801 | 1062 | 133 | N | | | | | | ⊗ | | | | |
| 15% | 41A | 2 | 3135 | 1132 | 142 | N | | | | | | ⊗ | | | | |
| 15% | 41A | 7 | 1852 | 1157 | 145 | N | | | | | | ⊗ | | | | |
| 15% | 41A | 8 | 2221 | 1157 | 145 | N | | | | | | ⊗ | | | | |
| 15% | 41A | 3 | 1632 | 1689 | 211 | N | | | | | | ⊗ | | | | |
| 25% | 42A | 6 | 2340 | 3619 | 452 | N | 8.2 | T,S | | | | | P | | X | |
| 25% | 42A | 4 | 2334 | 4133 | 517 | L | 8.8 | T | | | | ⊗ | X | + | ⊗ | 3 |

* Additional Notes:

1. Failed while pack was cycling at 50° C.
2. High end-of-charge voltage on cycle 219; cell was internally shorted by cycle 225.
3. Ceramic cracked around terminal.

TABLE Vf

GULTON 20 ah CELLS. DATA ON CELL FAILURES THROUGH 17 DECEMBER 1967

| Depth of Discharge | Pack Number | Cell Position in Pack | Cell Serial Number | Cycles Completed | Days of Cycling Completed | End-of-charge Voltage | Weight Loss (grams) | Deposits | High Pressure | Concave Sides | Ceramic Short | Migration | Blisters | Separator Deterioration | Additional Notes* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0° C; 1.5-hour orbit | | | | | | | | | | |
| 25% | 115A | 3 | 490 | 2107 | 132 | N | 26.9 | | | ⊗ | | | | | |
| 25% | 115A | 2 | 508 | 2203 | 138 | H | | | B | ⊗ | | | + | | |
| 25% | 115A | 4 | 467 | 2201 | 143 | H | | | B | ⊗ | | | ⊕ | | |
| 15% | 101A | 2 | 435 | 3111 | 194 | H | 24.6 | T | B | | | | | | |
| 15% | 101A | 5 | 407 | 3111 | 194 | H | 20.4 | T | | | | | | | |
| 15% | 101A | 4 | 438 | 3629 | 227 | H | 13.2 | T | B | X | | | + | | |
| | | | | | 0° C; 3-hour orbit | | | | | | | | | | |
| 15% | 102A | 2 | 449 | 135 | 17 | S | | | ⊗ | ⊗ | | | | | 1 |
| 25% | 116A | 3 | 428 | 8274 | 1034 | S | | | B | | | X | | ⊗ | |
| | | | | | 25° C; 1.5-hour orbit | | | | | | | | | | |
| 40% | 87A | 1 | 468 | 136 | 9 | H | 8.0 | | B | | | | | | |
| 40% | 87A | 2 | 388 | 208 | 13 | H | 26.7 | | | | ⊗ | | | | |
| 40% | 87A | 5 | 386 | 627 | 39 | L | 18.1 | | B | | ⊗ | | | | 2 |
| 40% | 87A | 3 | 394 | 627 | 39 | H | 16.4 | T | B | | ⊗ | | | | |
| 40% | 87A | 4 | 454 | 627 | 39 | L | 21.6 | T | | ⊗ | | | | | |
| 25% | 73A | 3 | 396 | 1776 | 111 | N | 23.7 | | | X | | | | | 3 |
| 25% | 73A | 1 | 387 | 6120 | 383 | L | 13.2 | | B | | | X | + | ⊗ | |
| 25% | 73A | 4 | 465 | 7763 | 485 | L | | T | | X | ⊗ | X | + | ⊗ | |
| | | | | | 25° C; 3-hour orbit | | | | | | | | | | |
| 40% | 88A | 1 | 404 | 151 | 19 | H | 25.0 | T | B | | | | | | |
| 40% | 88A | 2 | 422 | 151 | 19 | H | 25.0 | T | B | | | | | | |
| 40% | 88A | 3 | 466 | 358 | 45 | H | 16.4 | | B | | | | | | |
| 40% | 88A | 5 | 429 | 358 | 45 | L | | | | | ⊗ | | | | |
| 25% | 74A | 4 | 458 | 1184 | 148 | L | 14.2 | T | | | | | + | | |
| 25% | 74A | 3 | 419 | 1302 | 163 | N | 21.9 | T | | | | | | | |
| 25% | 74A | 2 | 440 | 1754 | 219 | N | 18.0 | T | | ⊗ | | X | | | |

* Additional Notes:

1. End of negative plates pushed int positive bus.
2. Burned spots on separator near top of plates.
3. Broken ceramic at negative seal.

**TABLE Vf (Contd)**

GULTON 20 ah CELLS. DATA ON CELL FAILURES THROUGH 17 DECEMBER 1967

| Depth of Discharge | Pack Number | Cell Position in Pack | Cell Serial Number | Cycles Completed | Days of Cycling Completed | End-of-charge Voltage | Weight Loss (grams) | Deposits | High Pressure | Concave Sides | Ceramic Short | Migration | Blisters | Extraneous Active Material | Separator Deterioration | Additional Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 50°-40° C; 1.5-hour orbit | | | | | | | | | | | | |
| 25% | 90A | 4 | 452 | 2824 | 177 | L | | | B,G | | | | | | ⊗ | |
| 25% | 90A | 5 | 457 | 2824 | 177 | N | | | B,G | | | | + | | | 1 |
| 25% | 90A | 3 | 378 | 4045 | 253 | S | | | | | ⊗ | | | | X | |
| 15% | 76A | 2 | 453 | 7697 | 481 | S | | T | | | | | | ⊗ | ⊗ | 2 |
| 15% | 76A | 4 | 431 | 7698 | 481 | S | | | B,G | | | Ⓟ | | | ⊗ | |
| 15% | 76A | 3 | 455 | 9348 | 584 | S | | | B,G | | | Ⓟ | + | | ⊗ | 1 |
| | | | | 50°-40° C; 3-hour orbit | | | | | | | | | | | | |
| 25% | 91A | 4 | 395 | 2862 | 358 | S | 6.8 | T | | | ⊗ | X | | | ⊗ | 3 |
| 25% | 91A | 3 | 412 | 3385 | 423 | S | | | B | | | X | | | ⊗ | |
| 25% | 91A | 1 | 489 | 4480 | 560 | S | | T | G | X | | Ⓟ | + | | ⊗ | |
| 25% | 91A | 2 | 447 | 4480 | 560 | S | | T | B | X | | Ⓟ | + | | ⊗ | |
| 15% | 77A | 2 | 462 | 5510 | 689 | S | | T | | X | | X | | | ⊗ | |
| 15% | 77A | 1 | 415 | 5684 | 711 | S | | | B,G | | | X | | | ⊗ | |
| 15% | 77A | 4 | 427 | 6032 | 754 | S | | T | B | | | X | | | ⊗ | |

* Additional Notes:

1. Small short circuit between plates; no obvious cause.
2. Broken ceramic at negative seal.
3. Broken ceramic on both terminals.

**TABLE Vg**

SONOTONE 5.0 ah CELLS. DATA ON CELL FAILURES THROUGH 17 DECEMBER 1967

| Depth of Discharge | Pack Number | Cell Position in Pack | Cell Serial Number | Cycles Completed | Days of Cycling Completed | End-of-charge Voltage | Weight Loss (grams) | Deposits | High Pressure | Pierced Separator | Migration | Extraneous Active Material | Weak Weld | Excess Scoring | Separator Deterioration | Additional Notes* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0° C; 1.5-hour orbit | | | | | | | | | | | |
| 15% | 49A | 9 | 6887 | 2010 | 126 | L | | | B | | (E) | | P | | | |
| 15% | 49A | 3 | 4370 | 10073 | 630 | S | | | | | X | X | | (S) | | |
| 25% | 50A | 5 | 4855 | 12069 | 754 | L | | | | (W) | X | | | X | | |
| 25% | 50A | 3 | 4366 | 13500 | 844 | L | 1.1 | T | | | (X) | | | X | | |
| 25% | 50A | 4 | 4854 | 15294 | 956 | L | | | | | X | | P | X | (S) | |
| | | | | | 0° C; 3-hour orbit (No Failures) | | | | | | | | | | | |

**TABLE Vg (Contd)**

SONOTONE 5.0 ah CELLS. DATA ON CELL FAILURES THROUGH 17 DECEMBER 1967

| Depth of Discharge | Pack Number | Cell Position in Pack | Cell Serial Number | Cycles Completed | Days of Cycling Completed | End-of-charge Voltage | Weight Loss (grams) | Deposits | High Pressure | Pierced Separator | Migration | Extraneous Active Material | Weak Weld | Excess Scoring | Separator Deterioration | Additional Notes* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 25° C; 1.5-hour orbit | | | | | | | | | | | |
| 25% | 1A | 4 | 4361 | 2995 | 187 | H | | T | | | X | | | | | 1 |
| 40% | 2A | 10 | 811 | 3155 | 197 | S | | T | B | (3) | | | P | | | |
| 40% | 2A | 5 | 3628 | 3992 | 250 | N | | T | B | | X | | | | | 2 |
| 40% | 2A | 2 | 3613 | 4411 | 276 | L | | | | | | | P | X | X | |
| 25% | 1A | 1 | 4335 | 4423 | 276 | H | | | | | | | P | X | C | |
| 40% | 2A | 6 | 3630 | 5262 | 329 | N | | T | B | (3) | X | | P | | X | |
| 40% | 2A | 7 | 3631 | 5262 | 329 | L | | | | (3) | X | | P | X | X | 3 |
| 40% | 2A | 1 | 3611 | 6671 | 417 | N | | T | B | | X | | | X | ⊗ | |
| 25% | 1A | 6 | 4878 | 7782 | 486 | N | | T | | | X | | | ⊗ | ⊗ | |
| 25% | 1A | 5 | 4868 | 11361 | 710 | N | | T | | | X | | | X | ⊗ | |
| 25% | 1A | 3 | 4345 | 11745 | 734 | N | | | | | X | | P | X | ⊗ | |
| 25% | 1A | 10 | 6802 | 11745 | 734 | N | | T | | | X | | P | X | ⊗ | |
| | | | | | 25° C; 3-hour orbit | | | | | | | | | | | |
| 40% | 6A | 8 | 4324 | 1069 | 134 | N | | | | | X | | | | | |
| 40% | 6A | 10 | 6904 | 1136 | 142 | L | | | | (W) | + | | | | | |
| 40% | 6A | 4 | 3637 | 1161 | 145 | S | | | | (W) | | ⊗ | P | | | 4 |
| 25% | 5A | 2 | 4351 | 3771 | 471 | H | | T | | | X | | | ⊗ | X | |
| 40% | 6A | 9 | 6875 | 3798 | 475 | N | | | B | | X | | | X | ⊗ | |
| 40% | 6A | 7 | 6882 | 4608 | 576 | N | | | | | (4) | | P | ⊗ | X | |
| 40% | 6A | 6 | 6880 | 5211 | 651 | N | | | | | X | | P | X | ⊗ | |
| 25% | 5A | 3 | 4354 | 5272 | 659 | N | | | G | | X | | P | X | X | |

* Additional Notes:

1. Foreign particle shorted adjacent plates through separator.
2. Defect (hole) in separator.
3. Separator torn at start of core exposing positive and negative plates.

**TABLE Vg (Contd)**

SONOTONE 5.0 ah CELLS. DATA ON CELL FAILURES THROUGH 17 DECEMBER 1967

| Depth of Discharge | Pack Number | Cell Position in Pack | Cell Serial Number | Cycles Completed | Days of Cycling Completed | End-of-charge Voltage | Weight Loss (grams) | Deposits | High Pressure | Pierced Separator | Migration | Extraneous Active Material | Weak Weld | Excess Scoring | Separator Deterioration | Additional Notes* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 50°-40° C; 1.5-hour orbit | | | | | | | | | | | | | | | | |
| 25% | 26A | 1 | 4323 | 2487 | 155 | S | | | | (W) | | | | | X | |
| 25% | 26A | 9 | 6773 | 2902 | 181 | S | | | G | | (E) | | P | | X | |
| 25% | 26A | 6 | 7224 | 2993 | 187 | N | | T | B | | X | | P | | X | |
| 25% | 26A | 7 | 7232 | 2993 | 187 | N | | T | B | | | | P | X | X | |
| 25% | 26A | 3 | 4881 | 3344 | 209 | S | | | | | | | | (S) | | |
| 25% | 26A | 4 | 4240 | 3625 | 227 | L | | | B | | P | | | | X | |
| 15% | 25A | 5 | 4852 | 6348 | 397 | H | | | | | P | | | (S) | (C) | |
| 15% | 25A | 4 | 4364 | 7052 | 441 | N | | T | B | | X | | | (S) | (S) | |
| 15% | 25A | 1 | 4317 | 7758 | 485 | L | | T | | | X | | | X | (S) | |
| 15% | 25A | 3 | 4350 | 9070 | 567 | N | | T | | (W) | | | | | (S) | 1 |
| 15% | 25A | 6 | 6850 | 9220 | 576 | N | | T | | | | (S) | | | | 1 |
| 15% | 25A | 2 | 4347 | 9328 | 583 | L | | T | | | X | | P | | X | |
| 50°-40° C; 3-hour orbit | | | | | | | | | | | | | | | | |
| 25% | 30A | 7 | 3657 | 855 | 107 | S | | | | | | | P | | (S) | 2 |
| 15% | 29A | 1 | 3626 | 1418 | 177 | S | | | | | (S) | | P | | | |
| 25% | 30A | 4 | 3643 | 3068 | 384 | L | | | | | (T) | | P | (S) | (S) | |
| 25% | 30A | 9 | 809 | 3068 | 384 | L | | T | | (W) | (T) | | | (S) | X | |
| 25% | 30A | 8 | 3658 | 3684 | 461 | L | 1.3 | T | | | X | | | (S) | (S) | |
| 25% | 30A | 1 | 3617 | 4141 | 518 | S | | T | | (W) | | | | | (S) | |
| 25% | 30A | 10 | 7230 | 4141 | 518 | L | | T | | | X | | | | (S) | |
| 15% | 29A | 8 | 4327 | 4340 | 543 | N | | T | | | | | | (S) | (S) | |
| 15% | 29A | 7 | 810 | 4835 | 604 | L | | T | | (W) | | | P | | | |
| 15% | 29A | 9 | 4340 | 4964 | 621 | N | | | | | X | | P | X | (S) | |
| 15% | 29A | 5 | 6883 | 5581 | 698 | N | | T | | | X | | P | X | (S) | |
| 15% | 29A | 6 | 808 | 5975 | 747 | N | 2.6 | T | | | X | | P | X | (C) | |

* Additional Notes:
1. Defect (hole) in separator.
2. Projection on positive plate wore through insulator and shorted to case.

F. Capacity Checks.

1. Initial Capacity Versus Temperature:

a. For each cell type, the average preconditioning capacity as the percent of rated capacity of each of the four packs at 0° C, 25° C and 50° C are listed and compared in Table VI below. For example, the average preconditioning capacity of the four packs of G.E. 3.0 ah cells at 0° C was about 118 percent of the rated 3.0 ah capacity. In comparing the average capacities at 0° and at 50° C with those at 25° C, for each cell type, it was found that the capacities at 0° C were from 83 to 95 percent of those at 25° C, with an average of 88 percent. At 50° C the range was from 38 to 57 percent of the 25° C capacities, with an average of 45 percent. For the 40° C preconditioning capacities this comparison is somewhat less meaningful because the packs had already cycled for varying amounts of time at 50° C and had probably been affected differently. As compared with the 25° C preconditioning capacities, those at 40° C ranged from 39 to 65 percent, averaging 55 percent.

b. Comparing preconditioning capacities at 40° C and 50° C in a similar manner, capacities at 40° C were from 101 to 140 percent of those at 50° C, the average for the seven cell types being 123 percent.

TABLE VI

| | AVERAGE PRECONDITIONING CAPACITIES AS PRECENT OF: RATED CAPACITY | | | | PRECONDITIONING CAPACITIES AT OTHER TEMPERATURES | | | |
|---|---|---|---|---|---|---|---|---|
| TYPE | 0° | 25° | 50° | 40° | 0°/25° | 50°/25° | 40°/25° | 40°/50° |
| G.E. 3.0 | 118 | 131 | 57 | 80 | 89 | 43 | 61 | 140 |
| G.E. 12 | 119 | 125 | 58 | 67 | 95 | 46 | 54 | 116 |
| Gould 3.5 | 98 | 118 | 45 | 55 | 83 | 38 | 46 | 123 |
| Gould 20 | 114 | 122 | 47 | 47 | 93 | 38 | 39 | 101 |
| Gulton 6.0 | 78 | 95 | 45 | 62 | 83 | 47 | 65 | 138 |
| Gulton 20 | 92 | 108 | 47 | 60 | 85 | 44 | 55 | 127 |
| Sonotone 5.0 | 105 | 117 | 67 | 76 | 90 | 57 | 65 | 114 |
| | | | | Minimum | 83 | 38 | 39 | 101 |
| | | | | Average | 88 | 45 | 55 | 123 |
| | | | | Maximum | 95 | 57 | 65 | 140 |

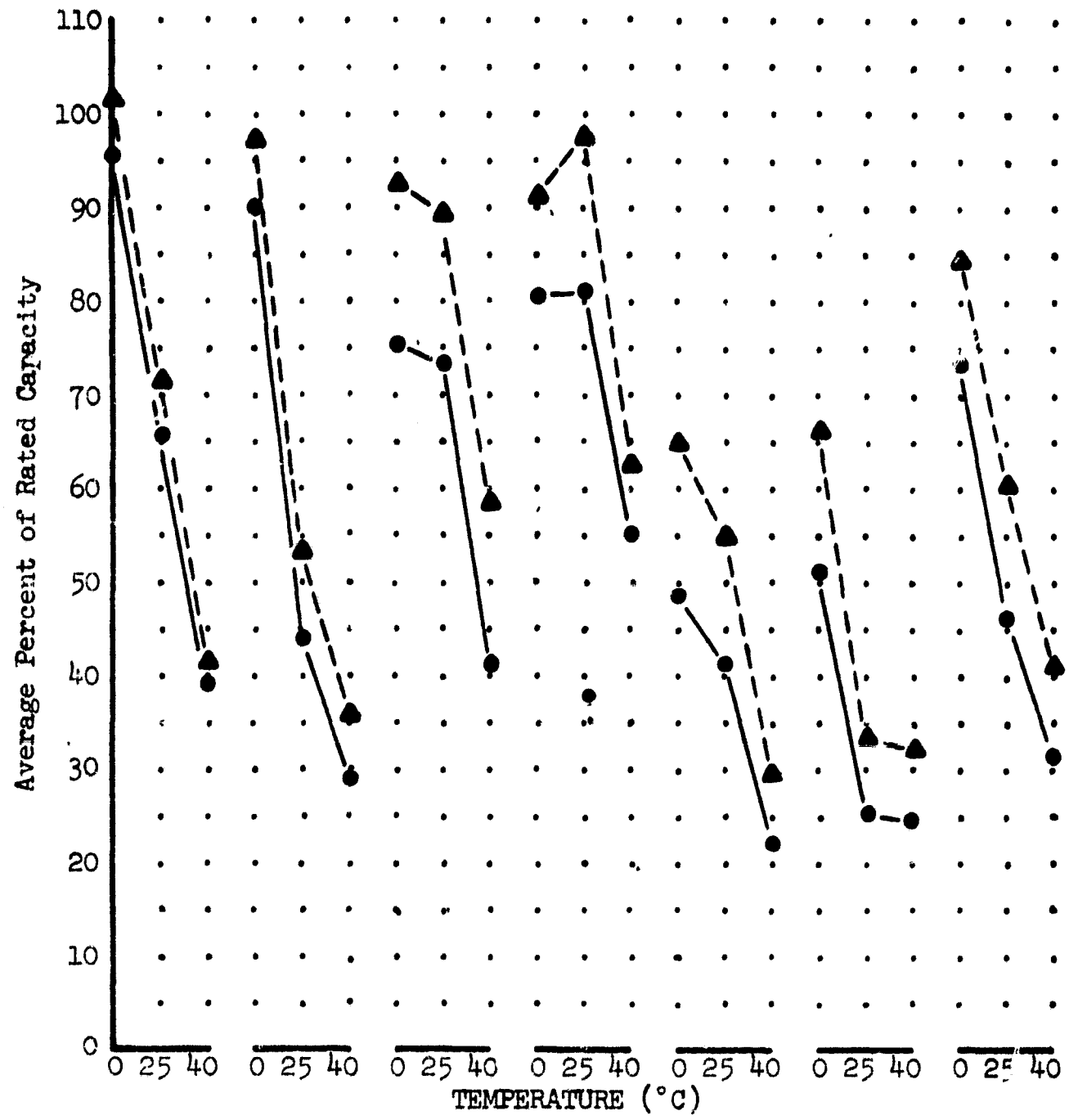
2. Obtainable Capacity Versus Temperature:

a. The capacity of the cells is affected by the temperature in which they are cycled. Figure 11 shows the average capacity, from all available capacity checks, as a percent of rated capacity plotted against the ambient temperature. The available capacity increased as the ambient temperature decreased, with the exception of the Gould 20 ah cells which showed maximum capacity at 25° C. This data indicates that the cells operate better at temperatures around 0° C. Since no packs were operated below 0° C, Figure 11 does not show an ambient temperature at which the cells would deliver the maximum available capacity, but it does indicate that packs operated below 25° C will deliver more of their rated capacity over an extended period of time.

3. Differences Between First and Second Discharges:

a. The first capacity discharge begins after completion of the regular cycling period. The second capacity discharge begins after completion of a 16-hour charge at the c/10 rate. At least three factors will affect differences in the ampere-hours delivered on the two discharges. First, the pack may not have been fully charged due to poor charge acceptance on cycling. Second, the so-called "Memory Effect" may limit the depth to which the cells can be discharged with the prescribed discharge rate and cutoff point (this is discussed further in paragraph IV.F.5.). The third factor is the charge rate. A lower charge rate will frequently result in a lower discharge capacity, especially at temperatures of 25° C or higher. Since the majority of packs receive a higher charge rate on cycling than on capacity check, this could partially offset the effects of the first two factors.

b. The first discharge capacity is usually somewhat less than the second. This is shown in Tables VIIa through VIIg and in Figure 11 where the second discharge is shown by the broken line. The greatest increases on the second discharge were shown by the Gould and Gulton cells at 0° C and 25° C. Among these, the greatest consistent difference in terms of rated capacity was 40 percent, as shown by Pack 3A (Gould 3.5 ah, 25 percent depth of discharge, 25° C, 1.5-hour orbit).




OBTAINABLE CAPACITY VERSUS TEMPERATURE

FIGURE 11

TABLE VIIa

G.E. 3.0 ah AMPERE-HOUR CAPACITIES ON PRECONDITIONING CYCLES AND CAPACITY CHECKS

| Temperature | | 50° - 40° C | | | | 25° C | | | | 0° C | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Depth of Discharge | | 25% | | 15% | | 40% | | 25% | | 25% | | 15% | |
| Orbit Period | | 1.5 | 3 | 1.5 | 3 | 1.5 | 3 | 1.5 | 3 | 1.5 | 3 | 1.5 | 3 |
| Pack Number | | 40A | 44A | 39A | 43A | 16A | 20A | 15A | 19A | 64A | 68A | 63A | 67A |
| Preconditioning Capacity | | 1.80 | 1.60 | 1.65 | 1.77 | 4.08 | 3.78 | 4.00 | 3.93 | 3.50 | 3.50 | 3.48 | 3.63 |
| Preconditioning Capacity at 40° | | 2.50 | 2.00 | 2.43 | 2.63 | | | | | | | | |
| 88 Days | Disch #1 | 0.73 | 1.17 | 2.10 | 2.20 | 2.37 | 2.98 | 3.38 | 3.78 | 3.30 | 3.25 | 3.15 | 3.25 |
| | Disch #2 | 0.88 | 1.35 | 1.92 | 1.98 | 2.75 | 3.00 | 3.28 | 3.70 | 3.33 | 3.35 | 3.18 | 3.12 |
| 176 Days | Disch #1 | 0.88 | 1.05 | 1.40 | 1.58 | 1.83 | 2.03 | 2.82 | 3.48 | 3.70 | 3.53 | 3.10 | 3.40 |
| | Disch #2 | 0.80 * | 1.19 | 1.53 | 1.61 | 2.10 | 2.35 | 2.93 | 3.48 | 3.53 | 3.35 | 3.12 | 3.25 |
| 264 Days | Disch #1 | | 1.08 | 0.95 | 1.53 | 1.35 | 1.68 | 2.17 | 3.05 | 3.30 | 3.30 | 2.90 | 3.53 |
| | Disch #2 | | 1.15 | 1.25 | 1.65 * | 1.33 * | 2.07 | 2.33 | 3.15 | 3.37 | 3.40 | 3.05 | 3.27 |
| 352 Days | Disch #1 | 0.98 | 0.85 | | | 1.20 | 1.70 | 2.70 | 3.28 | 3.20 | 2.88 | 2.90 | |
| | Disch #2 | 1.10 | 1.17 | | | 1.83 | 1.95 | 3.00 | 3.35 | 3.27 | 3.03 | 2.97 | |
| 440 Days | Disch #1 | 0.95 | 0.50 | | | 1.47 | 1.30 | 2.67 | 3.23 | 2.73 | 2.97 | 0.65 | |
| | Disch #2 | 0.95 | 0.70 * | | | 2.00 | 1.47 | 2.78 | 3.42 | 3.25 | 3.05 | 3.25 | |
| 528 Days | Disch #1 | 0.83 | | | | 1.43 | 0.78 | 2.40 | 2.93 | 2.58 | 2.70 | 2.95 | |
| | Disch #2 | 0.88 * | | | | 1.62 | 1.15 | 2.48 | 3.27 | 2.93 | 2.90 | 2.93 | |
| 616 Days | Disch #1 | | | | | 1.37 | 0.83 | 2.22 | 3.02 | 2.63 | 3.30 | 2.72 | |
| | Disch #2 | | | | | 1.47 | 1.10 * | 2.29 | 3.12 | 2.87 | 3.25 | 2.52 | |
| 704 Days | Disch #1 | | | | | 1.17 | | 2.12 | 2.80 | 1.88 | 3.05 | 3.04 | |
| | Disch #2 | | | | | 1.20 * | | 2.20 | 2.75 | 3.20 | 3.10 | 2.95 | |
| 792 Days | Disch #1 | | | | | | | 1.88 | 2.50 | 1.50 | 2.65 | 2.25 | |
| | Disch #2 | | | | | | | 1.88 | 2.70 | 2.78 | 2.55 | 3.08 | |
| 880 Days | Disch #1 | | | | | | | 2.00 | 2.67 | 2.75 | 2.37 | 2.95 | |
| | Disch #2 | | | | | | | 1.97 | 2.85 | 2.72 | 2.40 | 2.95 | |
| 968 Days | Disch #1 | | | | | | | 1.50 | 2.60 | 2.90 | 2.33 | 2.85 | |
| | Disch #2 | | | | | | | 1.60 | 2.55 | 3.05 | 2.48 | 3.25 | |
| 1056 Days | Disch #1 | | | | | | | 1.60 | 2.45 | 2.67 | 2.07 | 2.55 | |
| | Disch #2 | | | | | | | 1.70 | 2.42 | 2.75 | 2.30 | 2.82 | |
| 1144 Days | Disch #1 | | | | | | | 0.80 | 2.35 | 2.65 | 3.32 | 2.63 | |
| | Disch #2 | | | | | | | 1.40 | 2.42 | 2.63 | 3.00 | 2.30 | |
| 1232 Days | Disch #1 | | | | | | | 1.10 | 2.22 | 2.55 | 2.93 | 2.63 | |
| | Disch #2 | | | | | | | 1.28 | 2.15 | 2.60 | 2.63 | 2.67 | |
| 1320 Days | Disch #1 | | | | | | | 1.07 | 2.12 | 2.45 | | 3.08 | |
| | Disch #2 | | | | | | | 1.25 | 2.18 | 2.50 | | 3.00 | |

* Pack Failed

TABLE VIIb

G.E. 12 ah AMPERE-HOUR CAPACITIES ON PRECONDITIONING CYCLES AND CAPACITY CHECKS

| Temperature | | 50° - 40° C | | | | 25° C | | | | 0° C | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Depth of Discharge | | 25% | | 15% | | 40% | | 25% | | 25% | | 15% | |
| Orbit Period | | 1.5 | 3 | 1.5 | 3 | 1.5 | 3 | 1.5 | 3 | 1.5 | 3 | 1.5 | 3 |
| Pack Number | | 99A | 100A | 85A | 86A | 96A | 97A | 82A | 83A | 124A | 125A | 110A | 111A |
| Preconditioning Capacity | | 6.90 | 7.00 | 6.80 | 7.10 | 14.8 | 14.9 | 15.2 | 15.2 | 14.2 | 14.6 | 13.9 | 14.2 |
| Preconditioning Capacity at 40° | | 6.00 | 9.80 | 8.20 | 8.20 | | | | | | | | |
| 88 Days | Disch #1 | 3.42 | 2.90 | 4.80 | 6.30 | 5.00 | 5.00 | 8.00 | 11.7 | 13.2 | 11.8 | 10.8 | 11.7 |
| | Disch #2 | 4.90 | 3.80 | 5.00 | 5.90 | 6.00 | 5.60 | 7.80 | 11.5 | 13.5 | 13.0 | 12.7 | 13.2 |
| 176 Days | Disch #1 | 4.50 | 4.70 | 4.70 | 2.80 | 6.16 | 5.19 | 4.57 | 7.70 | 12.4 | 10.6 | 9.88 | 10.3 |
| | Disch #2 | 5.20 | 4.70 | 4.70 | 3.70 | 7.65 | 5.86 | 5.55 | 8.20 | 12.9 | 12.1 | 10.4 | 10.7 |
| 264 Days | Disch #1 | 3.90 | 3.15 | 4.26 | 2.70 | * | 5.70 | 3.90 | 4.90 | 11.8 | 11.0 | 12.0 | 10.3 |
| | Disch #2 | 4.40 | 5.70 | 5.00 | 4.00 | | 7.90 | 5.50 | 6.13 | 12.8 | 11.9 | 13.0 | 11.0 |
| 352 Days | Disch #1 | * | 4.10 | 4.10 | 2.70 | | 6.50 | 4.00 | 4.10 | 10.4 | 10.8 | 12.1 | 11.0 |
| | Disch #2 | | 5.10 | 4.90 | 3.50 | | 8.20 | 5.40 | 5.20 | 11.4 | 12.2 | 12.5 | 12.1 |
| 440 Days | Disch #1 | | 3.50 | 3.90 | 2.10 | | 5.90 | 5.40 | 3.50 | 10.5 | 13.0 | 14.1 | 13.6 |
| | Disch #2 | | 4.00 | 5.00 | 2.90 | | 6.80 | 5.70 | 4.80 | 11.5 | 12.9 | 14.1 | 12.9 |
| 528 Days | Disch #1 | | 3.20 | 1.80 | 2.30 | | 5.10 | 4.40 | 3.60 | 10.8 | 11.4 | 13.2 | 11.1 |
| | Disch #2 | | 4.00 | 1.90 | 2.10 | | 5.50 | 5.00 | 4.40 | 11.7 | 11.7 | 13.7 | 12.0 |
| 616 Days | Disch #1 | | * | 2.10 | 1.90 | | 5.60 | 4.10 | 3.80 | 9.70 | 10.7 | 12.9 | 10.9 |
| | Disch #2 | | | 4.30 | 4.40 | | 5.70 | 4.90 | 5.10 | 10.8 | 11.2 | 14.3 | 11.4 |
| 704 Days | Disch #1 | | | * | 2.60 | | * | * | 4.00 | 7.20 | 10.6 | 11.5 | 10.2 |
| | Disch #2 | | | | 3.70 | | | | 5.60 | 8.40 | 11.3 | 13.0 | 11.2 |
| 792 Days | Disch #1 | | | | 2.60 | | | | 4.30 | 5.00 | 10.5 | 10.5 | 10.0 |
| | Disch #2 | | | | 3.10 | | | | 7.20 | 7.20 | 10.9 | 11.9 | 10.0 |
| 880 Days | Disch #1 | | | | 2.40 | | | | 4.30 | 8.00 | 10.1 | 11.4 | 9.80 |
| | Disch #2 | | | | 3.40 | | | | 6.80 | 10.5 | 10.9 | 12.0 | 10.3 |
| 968 Days | Disch #1 | | | | 2.20 | | | | 4.50 | 7.40 | 10.9 | 10.5 | 9.80 |
| | Disch #2 | | | | 2.90 | | | | 6.80 | 10.1 | 11.3 | 11.5 | 10.2 |
| 1056 Days | Disch #1 | | | | 2.20 | | | | 3.00 | 8.00 | 10.4 | 8.40 | 9.90 |
| | Disch #2 | | | | 2.00 | | | | 6.20 | 9.80 | 10.9 | 12.0 | 10.2 |
| 1144 Days | Disch #1 | | | | 2.30 | | | | 4.40 | 7.00 | 9.90 | 10.4 | 9.50 |
| | Disch #2 | | | | 3.10 | | | | 5.70 | 11.2 | 10.5 | 11.7 | 9.80 |
| 1232 Days | Disch #1 | | | | 1.90 | | | | 4.10 | 7.50 | 9.60 | 9.90 | 8.70 |
| | Disch #2 | | | | 2.30 | | | | 5.30 | 8.90 | 10.3 | 11.7 | 9.20 |
| 1320 Days | Disch #1 | | | | 1.50 | | | | 4.00 | 5.00 | | 12.1 | |
| | Disch #2 | | | | 1.50 | | | | 4.90 | 8.30 | | 12.0 | |

* Pack Failed

TABLE VIIc

GOULD 3.5 ah AMPERE-HOUR CAPACITIES ON PRECONDITIONING CYCLES AND CAPACITY CHECKS

| Temperature | | 50° - 40° C | | | | 25° C | | | | 0° C | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Depth of Discharge | | 25% | | 15% | | 40% | | 25% | | 25% | | 15% | |
| Orbit Period | | 1.5 | 3 | 1.5 | 3 | 1.5 | 3 | 1.5 | 3 | 1.5 | 3 | 1.5 | 3 |
| Pack Number | | 28A | 32A | 27A | 31A | 4A | 8A | 3A | 7A | 52A | 56A | 51A | 55A |
| Preconditioning Capacity | | 1.55 | 1.55 | 1.52 | 1.60 | 3.94 | 4.29 | 3.97 | 4.32 | 3.33 | 3.50 | 3.62 | 3.27 |
| Preconditioning Capacity at 40° | | 2.07 | 1.66 | 2.63 | 1.31 | | | | | | | | |
| 88 Days | Disch #1 | 1.90 | 0.82 | 2.07 | 1.66 | 3.30 | 3.68 | 2.51 | 3.94 | 3.72 | 3.82 | 3.97 | 3.06 |
| | Disch #2 | 2.86 | 1.49 | 1.93 | 1.75 | 3.38 | 3.65 | 3.82 | 4.03 | 3.85 | 3.91 | 4.00 | 3.59 |
| | | * | * | | | | | | | | | | |
| 176 Days | Disch #1 | | | 1.72 | 1.66 | 2.07 | 3.30 | 1.46 | 3.79 | 3.35 | 3.18 | 3.06 | 2.83 |
| | Disch #2 | | | 1.95 | 1.98 | 2.77 | 3.35 | 2.92 | 3.76 | 3.53 | 3.58 | 3.33 | 3.15 |
| | | | | | | * | | | | | | | |
| 264 Days | Disch #1 | | | 0.64 | 1.49 | | 2.54 | 1.20 | 3.41 | 2.51 | 3.24 | 2.83 | 3.21 |
| | Disch #2 | | | 1.90 | 2.16 | | 3.03 | 2.25 | 3.52 | 3.18 | 3.65 | 3.41 | 3.38 |
| | | | | * | * | | * | * | | | | | |
| 352 Days | Disch #1 | | | | | | 1.63 | 1.23 | 3.21 | 2.71 | 2.60 | | |
| | Disch #2 | | | | | | 2.77 | 3.30 | 3.41 | 3.21 | 3.33 | | |
| 440 Days | Disch #1 | | | | | | 1.23 | 2.19 | 3.00 | 2.65 | 2.63 | | |
| | Disch #2 | | | | | | 2.28 | 3.24 | 3.38 | 3.35 | 3.27 | | |
| 528 Days | Disch #1 | | | | | | 2.01 | 1.08 | 2.51 | 2.19 | 2.48 | | |
| | Disch #2 | | | | | | 2.51 | 2.80 | 3.30 | 3.15 | 3.03 | | |
| | | | | | | | * | | | | | | |
| 616 Days | Disch #1 | | | | | | | 2.33 | 3.12 | 1.55 | 2.36 | | |
| | Disch #2 | | | | | | | 2.65 | 3.27 | 3.47 | 2.77 | | |
| 704 Days | Disch #1 | | | | | | | 2.16 | 3.15 | 1.34 | 2.83 | | |
| | Disch #2 | | | | | | | 2.96 | 3.24 | 3.00 | 3.73 | | |
| 792 Days | Disch #1 | | | | | | | 1.55 | 2.77 | 2.42 | 2.04 | | |
| | Disch #2 | | | | | | | 2.42 | 2.92 | 2.83 | 2.60 | | |
| | | | | | | | | * | | | | | |
| 880 Days | Disch #1 | | | | | | | | 2.71 | 3.00 | 2.89 | | |
| | Disch #2 | | | | | | | | 2.83 | 3.21 | 3.15 | | |
| 968 Days | Disch #1 | | | | | | | | 2.68 | 2.48 | 2.63 | | |
| | Disch #2 | | | | | | | | 2.83 | 2.92 | 3.18 | | |
| 1056 Days | Disch #1 | | | | | | | | 2.39 | 2.45 | 1.84 | | |
| | Disch #2 | | | | | | | | 2.77 | 3.03 | 3.12 | | |
| 1144 Days | Disch #1 | | | | | | | | 1.84 | 1.11 | 2.28 | | |
| | Disch #2 | | | | | | | | 2.63 | 2.83 | 3.15 | | |
| 1232 Days | Disch #1 | | | | | | | | 2.16 | 1.93 | 2.63 | | |
| | Disch #2 | | | | | | | | 2.30 | 2.45 | 3.06 | | |
| 1320 Days | Disch #1 | | | | | | | | 2.63 | 2.39 | 2.45 | | |
| | Disch #2 | | | | | | | | 2.54 | 2.48 | 3.00 | | |

* Pack Failed

## TABLE VIId

GOULD 20 ah AMPERE-HOUR CAPACITIES ON PRECONDITIONING CYCLES AND CAPACITY CHECKS

| Temperature | | 50° - 40° C | | | | 25° C | | | | 0° C | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Depth of Discharge | | 25% | | 15% | | 40% | | 25% | | 25% | | 15% | |
| Orbit Period | | 1.5 | 3 | 1.5 | 3 | 1.5 | 3 | 1.5 | 3 | 1.5 | 3 | 1.5 | 3 |
| Pack Number | | 126A | 122A | 112A | 108A | 118A | 119A | 104A | 105A | 98A | 94A | 84A | 80A |
| Preconditioning Capacity | | 9.00 | 9.33 | 9.60 | 9.50 | 24.7 | 24.7 | 25.0 | 23.3 | 23.3 | 23.0 | 22.5 | 23.0 |
| Preconditioning Capacity at 40° | | 13.9 | 7.50 | 6.50 | 9.67 | | | | | | | | |
| 88 Days | Disch #1 | 15.0 | 4.67 | 15.7 | 11.8 | 23.0 | 17.5 | 11.8 | 22.2 | 19.0 | 15.0 | 25.7 | 18.7 |
| | Disch #2 | 15.2 * | 8.17 * | 12.2 | 9.83 | 23.3 * | 24.7 | 18.5 | 23.5 | 21.2 | 17.5 | 27.7 | 23.2 |
| 176 Days | Disch #1 | | | 15.2 | 14.2 | | 21.7 | 12.2 | 19.3 | 7.60 | 13.3 | 24.2 | 20.0 |
| | Disch #2 | | | 15.3 | 14.8 | | 19.5 * | 14.0 * | 22.2 | 15.2 | 25.0 | 26.5 | 21.5 |
| 264 Days | Disch #1 | | | 3.50 | 14.2 | | | | 19.7 | 14.8 | 16.3 | 23.0 | 17.0 |
| | Disch #2 | | | 12.5 | 16.8 | | | | 21.3 | 18.7 | 18.2 | 24.2 | 20.3 |
| 352 Days | Disch #1 | | | 9.09 | 14.8 | | | | 19.2 | 17.2 | 16.7 | 22.8 | 25.8 |
| | Disch #2 | | | 12.4 * | 15.2 | | | | 21.2 | 16.7 | 18.8 | 24.7 | 20.0 |
| 440 Days | Disch #1 | | | | 12.2 | | | | 15.8 | 14.1 | 14.8 | 17.5 | 16.3 |
| | Disch #2 | | | | 12.3 * | | | | 20.7 | 17.5 | 16.8 | 21.7 | 19.7 |
| 528 Days | Disch #1 | | | | | | | | 9.00 | 12.3 | 14.8 | 19.5 | 15.5 |
| | Disch #2 | | | | | | | | 10.5 | 13.5 | 17.0 | 22.3 | 18.3 |
| 616 Days | Disch #1 | | | | | | | | 20.5 | 9.83 | 14.0 | 19.2 | 14.7 |
| | Disch #2 | | | | | | | | 17.2 | 13.5 * | 15.8 | 19.8 | 16.7 |
| 704 Days | Disch #1 | | | | | | | | 1.67 | | 13.3 | 16.2 | 13.7 |
| | Disch #2 | | | | | | | | 14.3 * | | 15.8 | 19.0 | 16.5 |
| 792 Days | Disch #1 | | | | | | | | | | 12.2 | 16.2 | 17.0 |
| | Disch #2 | | | | | | | | | | 14.7 | 18.5 | 17.2 |
| 880 Days | Disch #1 | | | | | | | | | | 13.2 | 11.3 | 11.7 |
| | Disch #2 | | | | | | | | | | 15.2 | 16.3 | 15.0 |
| 968 Days | Disch #1 | | | | | | | | | | 11.7 | 12.0 | 13.5 |
| | Disch #2 | | | | | | | | | | 16.2 | 16.8 | 14.3 |
| 1056 Days | Disch #1 | | | | | | | | | | 5.67 | 16.8 | 10.2 |
| | Disch #2 | | | | | | | | | | 12.5 | 18.8 | 14.5 |
| 1144 Days | Disch #1 | | | | | | | | | | 13.0 | 14.0 | 11.5 |
| | Disch #2 | | | | | | | | | | 14.3 | 15.5 | 14.3 |
| 1232 Days | Disch #1 | | | | | | | | | | 11.5 | 13.5 | 9.80 |
| | Disch #2 | | | | | | | | | | 14.0 | 16.5 | 13.5 |

* Pack Failed

**TABLE VII.**

**GULTON 6.0 ah AMPERE-HOUR CAPACITIES ON PRECONDITIONING CYCLES AND CAPACITY CHECKS**

| Temperature | | 50° - 40° C | | | | 25° C | | | | 0° C | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Depth of Discharge | | 25% | | 15% | | 40% | | 25% | | 25% | | 15% | |
| Orbit Period | | 1.5 | 3 | 1.5 | 3 | 1.5 | 3 | 1.5 | 3 | 1.5 | 3 | 1.5 | 3 |
| Pack Number | | 38A | 42A | 37A | 41A | 14A | 18A | 13A | 17A | 62A | 66A | 61A | 65A |
| Preconditioning Capacity | | 2.65 | 2.60 | 2.75 | 2.75 | 6.40 | 4.55 | 5.80 | 5.80 | 5.00 | 4.25 | 5.00 | 4.50 |
| Preconditioning Capacity at 40° | | 2.90 | 3.80 | 3.60 | 4.55 | | | | | | | | |
| 88 Days | Disch #1 | 1.30 | 1.60 | 0.80 | 1.80 | 2.63 | 4.15 | 2.34 | 1.70 | 1.40 | 2.80 | 5.10 | 4.65 |
| | Disch #2 | 1.55 * | 2.15 | 1.70 | 2.05 | 3.45 * | 4.95 | 2.75 | 3.65 | 4.75 | 5.00 | 5.10 | 5.45 |
| 176 Days | Disch #1 | | 1.85 | 2.95 | 1.20 | | 2.10 | 1.60 | 2.95 | 2.60 | 1.50 | 4.65 | 5.00 |
| | Disch #2 | | 2.10 | 2.20 | 1.63 * | | 3.16 * | 2.85 | 3.45 | 3.80 | 3.50 | 5.40 | 5.35 |
| 264 Days | Disch #1 | | 1.82 | 0.80 | | | | 2.10 | 2.00 | 3.15 | 1.50 | 3.70 | 4.75 |
| | Disch #2 | | 2.35 | 1.85 | | | | 2.70 * | 2.50 | 4.35 | 2.50 | 4.45 | 5.15 |
| 352 Days | Disch #1 | | 1.60 | 1.15 | | | | 2.05 | 2.65 | 2.40 | 2.25 | 5.04 | |
| | Disch #2 | | 1.85 | 2.00 * | | | | 2.30 * | 3.55 | 3.80 | 3.15 | 4.50 | |
| 440 Days | Disch #1 | | 1.45 | | | | | | 2.30 | 2.20 | 1.35 | 4.10 | |
| | Disch #2 | | 1.50 | | | | | | 3.30 | 3.90 | 2.60 | 4.50 | |
| 528 Days | Disch #1 | | 1.25 | | | | | | 2.75 | 2.30 | 0.90 | 4.20 | |
| | Disch #2 | | 1.30 * | | | | | | 3.30 | 3.45 * | 2.15 | 5.15 | |
| 616 Days | Disch #1 | | | | | | | | 3.45 | | 1.70 | 3.90 | |
| | Disch #2 | | | | | | | | 3.95 | | 1.75 * | 4.20 | |
| 704 Days | Disch #1 | | | | | | | | 3.05 | | | 3.15 | |
| | Disch #2 | | | | | | | | 3.85 | | | 4.10 | |
| 792 Days | Disch #1 | | | | | | | | 2.85 | | | 3.24 | |
| | Disch #2 | | | | | | | | 3.95 | | | 3.70 | |
| 880 Days | Disch #1 | | | | | | | | 2.90 | | | 3.15 | |
| | Disch #2 | | | | | | | | 3.80 | | | 3.65 | |
| 968 Days | Disch #1 | | | | | | | | 2.65 | | | 3.35 | |
| | Disch #2 | | | | | | | | 3.50 | | | 3.70 | |
| 1056 Days | Disch #1 | | | | | | | | 2.50 | | | 2.70 | |
| | Disch #2 | | | | | | | | 3.35 | | | 3.15 | |
| 1144 Days | Disch #1 | | | | | | | | 2.15 | | | 2.75 | |
| | Disch #2 | | | | | | | | 3.20 | | | 3.15 | |
| 1232 Days | Disch #1 | | | | | | | | 2.15 | | | | |
| | Disch #2 | | | | | | | | 3.10 | | | | |
| 1320 Days | Disch #1 | | | | | | | | 2.30 | | | | |
| | Disch #2 | | | | | | | | 3.25 | | | | |

* Pack Failed

TABLE VIIf

GULTON 20 ah AMPERE-HOUR CAPACITIES ON PRECONDITIONING CYCLES AND CAPACITY CHECKS

| Temperature | | 50° - 40° C | | | | 25° C | | | | 0° C | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Depth of Discharge | | 25% | | 15% | | 40% | | 25% | | 25% | | 15% | |
| Orbit Period | | 1.5 | 3 | 1.5 | 3 | 1.5 | 3 | 1.5 | 3 | 1.5 | 3 | 1.5 | 3 |
| Pack Number | | 90A | 91A | 76A | 77A | 87A | 88A | 73A | 74A | 115A | 116A | 101A | 102A |
| Preconditioning Capacity | | 10.10 | 9.67 | 10.3 | 9.50 | 23.3 | 19.8 | 23.3 | 20.4 | 17.7 | 21.7 | 17.2 | 16.7 |
| Preconditioning Capacity at 40° | | 11.3 | 10.3 | 13.8 | 12.7 | | | | | | | | |
| 88 Days | Disch #1 | 4.50 | 4.50 | 6.00 | 5.67 | * | * | 5.67 | 4.00 | 4.83 | 20.1 | 12.5 | 18.8 |
| | Disch #2 | 6.00 | 6.67 | 6.50 | 7.33 | | | 7.17 | 6.17 | 11.2 * | 20.7 | 12.2 | 18.3 |
| 176 Days | Disch #1 | 9.17 | 4.83 | 3.67 | 3.67 | | | 6.60 | 4.83 | | 20.8 | 3.00 | 21.0 |
| | Disch #2 | 10.3 | 6.67 | 4.83 | 5.33 | | | 9.50 | 7.17 * | | 21.8 | 5.67 * | 25.2 |
| 264 Days | Disch #1 | 7.33 | 6.17 | 3.93 | 3.17 | | | 5.33 | | | 17.7 | | 20.2 |
| | Disch #2 | 9.33 * | 7.67 | 5.50 | 4.33 | | | 7.83 | | | 19.3 | | 20.3 |
| 352 Days | Disch #1 | 5.67 | 3.50 | 3.83 | | | | 5.67 | | | 8.67 | | 8.33 |
| | Disch #2 | 6.83 | 4.67 | 5.33 | | | | 8.67 | | | 17.5 | | 19.5 |
| 440 Days | Disch #1 | 5.33 | 2.67 | 3.00 | | | | 5.50 | | | 14.2 | | 15.5 |
| | Disch #2 | 7.17 | 5.00 | 4.67 | | | | 8.83 * | | | 15.2 | | 17.3 |
| 528 Days | Disch #1 | 5.00 | 3.97 | 3.33 | | | | | | | 13.2 | | 17.0 |
| | Disch #2 | 5.50 * | 5.17 * | 5.00 | | | | | | | 15.8 | | 16.7 |
| 616 Days | Disch #1 | | | 3.33 | | | | | | | 13.2 | | 13.5 |
| | Disch #2 | | | 5.17 | | | | | | | 13.5 | | 15.0 |
| 704 Days | Disch #1 | | | 3.00 | | | | | | | 11.7 | | 11.5 |
| | Disch #2 | | | 6.16 * | | | | | | | 13.2 | | 14.8 |
| 792 Days | Disch #1 | | | | | | | | | | 11.0 | | 9.83 |
| | Disch #2 | | | | | | | | | | 13.0 | | 10.1 |
| 880 Days | Disch #1 | | | | | | | | | | 9.00 | | 8.17 |
| | Disch #2 | | | | | | | | | | 12.0 | | 10.0 |
| 968 Days | Disch #1 | | | | | | | | | | 5.17 | | 7.16 |
| | Disch #2 | | | | | | | | | | 10.7 | | 8.67 |
| 1056 Days | Disch #1 | | | | | | | | | | 9.17 | | 7.00 |
| | Disch #2 | | | | | | | | | | 13.8 | | 8.17 |
| 1144 Days | Disch #1 | | | | | | | | | | 10.2 | | 6.00 |
| | Disch #2 | | | | | | | | | | 13.0 | | 7.50 |
| 1232 Days | Disch #1 | | | | | | | | | | 8.67 | | 5.67 |
| | Disch #2 | | | | | | | | | | 11.8 | | 6.83 |

* Pack Failed

## TABLE VIIg

SONOTONE 5.0 ah AMPERE-HOUR CAPACITIES ON PRECONDITIONING CYCLES AND CAPACITY CHECKS

| Temperature | | 50° - 40° C | | | | 25° C | | | | 0° C | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Depth of Discharge | | 25% | | 15% | | 40% | | 25% | | 25% | | 15% | |
| Orbit Period | | 1.5 | 3 | 1.5 | 3 | 1.5 | 3 | 1.5 | 3 | 1.5 | 3 | 1.5 | 3 |
| Pack Number | | 26A | 30A | 25A | 29A | 2A | 6A | 1A | 5A | 50A | 54A | 49A | 53A |
| Preconditioning Capacity | | 3.17 | 3.75 | 3.08 | 3.33 | 6.42 | 5.83 | 5.42 | 5.13 | 5.04 | 4.92 | 5.45 | 3.62 |
| Preconditioning Capacity at 40° | | 3.17 | 3.50 | 3.63 | 4.92 | | | | | | | | |
| 88 Days | Disch #1 | 1.63 | 1.63 | 1.92 | 1.92 | 3.79 | 3.04 | 3.25 | 4.17 | 4.58 | 3.63 | 3.67 | 5.75 |
| | Disch #2 | 2.75 | 1.88 | 2.25 | 2.75 | 4.38 | 4.50 | 3.67 | 4.58 | 4.96 | 3.96 | 5.54 | 5.79 |
| 176 Days | Disch #1 | 2.93 | 2.17 | 1.38 | 1.38 | 3.38 | 2.50 | 1.92 | 2.42 | 4.25 | 3.50 | 5.08 | 5.38 |
| | Disch #2 | 2.67 | 2.88 | 1.83 | 2.38 | 4.17 | 3.29 | 2.33 | 3.04 | 4.58 | 3.96 | 5.50 | 5.67 |
| 264 Days | Disch #1 | | 1.54 | 2.04 | 1.17 | 2.46 | 2.42 | 2.21 | 1.29 | 3.83 | 3.42 | 4.79 | 5.21 |
| | Disch #2 | | 2.38 | 2.04 | 2.42 | 3.25 | 3.25 | 2.88 | 2.04 | 4.25 | 4.13 | 4.96 | 5.42 |
| 352 Days | Disch #1 | 1.13 | 0.96 | 1.25 | 2.12 | 2.71 | 1.67 | 1.67 | 3.17 | 3.33 | 4.46 | 4.65 | |
| | Disch #2 | 1.67 | 1.17 | 2.08 | 3.00 * | 2.92 | 2.79 | 2.13 | 3.79 | 3.96 | 4.79 | 5.33 | |
| 440 Days | Disch #1 | 1.08 | 0.75 | 1.04 | | 2.21 | 1.38 | 1.42 | 3.29 | 3.17 | 3.21 | 4.75 | |
| | Disch #2 | 1.21 * | 1.17 | 1.96 | | 2.33 | 2.21 | 2.13 | 3.67 | 3.75 | 4.17 | 5.50 | |
| 528 Days | Disch #1 | | 0.71 | 1.04 | | 2.33 | 1.79 | 1.38 | 2.92 | 3.00 | 2.92 | 4.75 | |
| | Disch #2 | | 1.54 | 1.29 | | 1.92 | 2.58 | 2.08 | 3.67 | 3.29 | 4.50 | 5.54 | |
| 616 Days | Disch #1 | | 0.58 | 1.79 | | 2.00 | 1.25 | 1.54 | 2.79 | 3.04 | 4.21 | 5.00 | |
| | Disch #2 | | 0.83 * | 1.54 * | | 1.83 | 2.80 | 2.21 | 3.46 | 3.38 | 4.54 | 4.96 | |
| 704 Days | Disch #1 | | | | | 2.08 | 1.54 | 1.75 | 2.46 | 2.42 | 3.75 | 4.33 | |
| | Disch #2 | | | | | 2.13 * | 2.46 * | 3.25 | 3.25 | 3.13 | 4.08 | 4.62 | |
| 792 Days | Disch #1 | | | | | | | 2.29 | 2.67 | 2.50 | 3.75 | 4.08 | |
| | Disch #2 | | | | | | | 3.42 | 3.58 | 2.46 | 4.04 | 4.17 | |
| 880 Days | Disch #1 | | | | | | | 2.83 | 2.50 | 2.08 | 3.63 | 4.17 | |
| | Disch #2 | | | | | | | 3.67 | 3.33 | 2.75 | 4.13 | 4.63 | |
| 968 Days | Disch #1 | | | | | | | 2.42 | 2.29 | 1.96 | 3.33 | 4.17 | |
| | Disch #2 | | | | | | | 3.33 | 3.13 | 2.50 | 3.88 | 4.71 | |
| 1056 Days | Disch #1 | | | | | | | 1.38 | 2.13 | 1.54 | 3.13 | 3.92 | |
| | Disch #2 | | | | | | | 2.29 | 3.25 | 2.08 | 3.71 | 4.33 | |
| 1144 Days | Disch #1 | | | | | | | 2.46 | 1.96 | 1.38 | 3.13 | 3.71 | |
| | Disch #2 | | | | | | | 2.88 | 3.04 | 1.92 | 3.88 | 4.38 | |
| 1232 Days | Disch #1 | | | | | | | | 1.83 | 1.25 | 2.46 | 3.67 | |
| | Disch #2 | | | | | | | | 2.96 | 1.92 | 3.38 | 4.13 | |
| 1320 Days | Disch #1 | | | | | | | | 1.75 | 1.21 | | 3.75 | |
| | Disch #2 | | | | | | | | 2.92 | 1.67 | | 4.17 | |

* Pack Failed

4. Capacity Versus Days of Cycling:

a. In general the capacity at 40° C and 25° C continues to drop throughout the life of the cells whereas at 0° C the capacity remains about the same as shown in Figures 12(A) through 12(G). Sometimes the capacity of a pack is lowered by one cell. For example, Pack 105A (Gould 20 ah, 25° C, 25 percent depth of discharge, and 3-hour orbit period) delivered about 100 percent of its rated capacity after 440 days of cycling but only 53 percent after 528 days. However, after removal of the failed cell, the pack again delivered about 100 percent of its rated capacity, in ampere-hours, at the capacity check following 616 days of cycling.

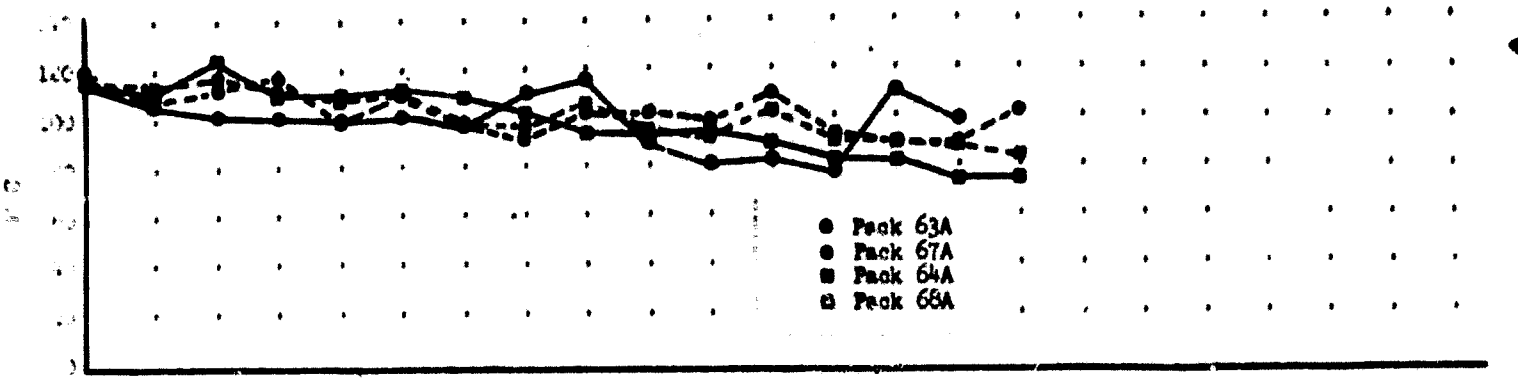
b. In order to compare changes in capacity with time, a procedure similar to that used for comparing temperature effects was used. All comparisons are between the second discharge of the third capacity check (after 264 days of cycling) and the preconditioning capacity. (For detailed explanation of preconditioning capacity and capacity checks see paragraph III.G.) Because of pack failures after the third capacity check on some cell types, this type of comparison is not practical on those types after this capacity check. For example, among the G.E. 3.0 ah cells at 40° C, one of the original four packs failed before its third capacity check. Only the remaining three were included in the comparisons at 40° C, so that for these particular packs the average capacity on preconditioning at 40° C was 78.4 percent of rated capacity, and that on the third capacity check was 45 percent of the rated capacity. The 264-day capacity was therefore 45/78.4 or 57.4 percent of the preconditioning capacity. Similar computations for all of the cell types at each temperature showed that at 0° C the 264-day capacities ranged from 85.6 to 103.1 percent of the 0° C preconditioning capacities, the average being 92.6 percent. Likewise at 25° C the 264-day capacities ranged from 33.6 to 91.4 percent of the 25° C preconditioning capacities, the average being 55 4 percent. At the 40° C, 264-day capacities ranged from 48.9 to 117.5 percent of the 40° C preconditioning capacities, the average being 79.9 percent. Results at 40° C are again complicated by the prior cycling at 50° C. The unusual rise to 177.5 percent was by the two Gould 20 ah packs at 15 percent depth of discharge, of which one had an unusually low preconditioning capacity and the other showed an increase in capacity with each capacity check.

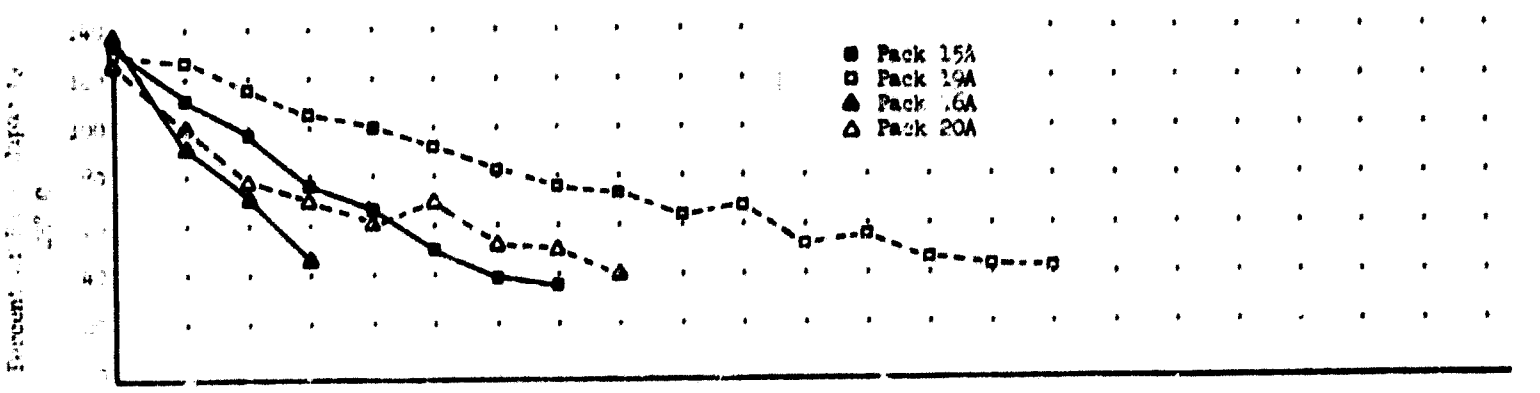
c. Except for the Gould cells at 25° C and 40° C, which retained a much higher percentage of their preconditioning capacities after 264 days of cycling, the capacity losses at each temperature for all cell types after 264 days of cycling were within a fairly narrow range, as shown in Table VIII. At 40° C, the apparently high percentage of the preconditioning capacity retained by the Gould cells after 264 days of cycling is due partly to the comparatively low preconditioning capacity.

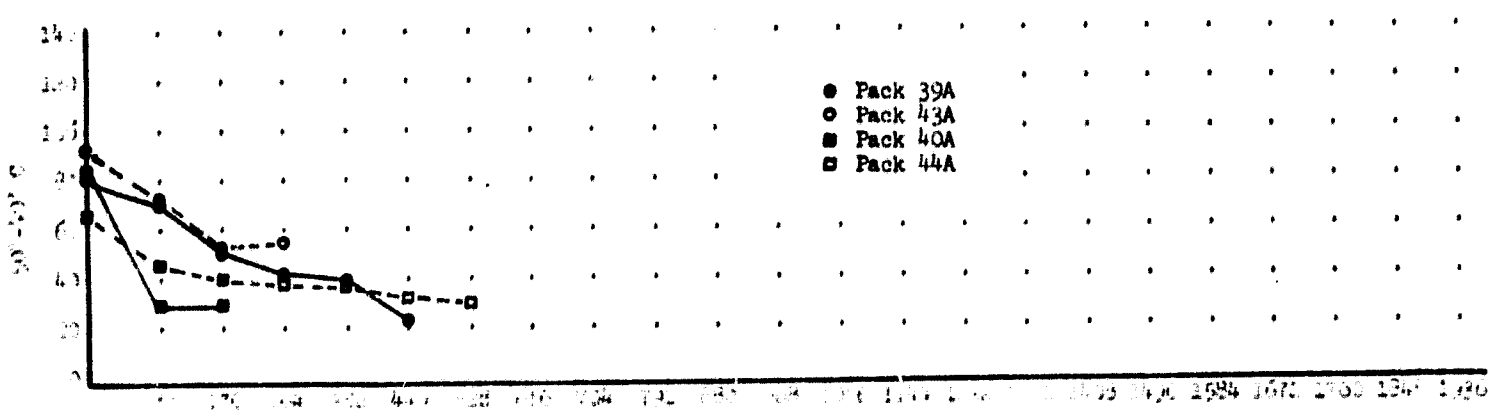
TABLE VIII

COMPARISON OF CAPACITIES AFTER 264 DAYS CYCLING AS PERCENT OF RATED AND INITIAL (PRECONDITIONING) CAPACITIES

| Manufacturer and Type (a.h.) | AT 0° C Number of Packs | Preconditioning Percent of Rated | After 264 Days of Cycling Percent of Rated | After 264 Days of Cycling Percent of Precondition. | AT 25° C Number of Packs | Preconditioning Percent of Rated | After 264 Days of Cycling Percent of Rated | After 264 Days of Cycling Percent of Precondition. | AT 40° C Number of Packs | Preconditioning Percent of Rated | After 264 Days of Cycling Percent of Rated | After 264 Days of Cycling Percent of Precondition. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| G.E. 3.0 | 4 | 117.6 | 111.3 | 94.6 | 4 | 131.6 | 74.2 | 56.4 | 3 | 78.4 | 45.0 | 57.4 |
| G.E. 12 | 4 | 118.6 | 101.5 | 85.6 | 3 | 125.8 | 54.3 | 43.2 | 4 | 67.1 | 39.8 | 59.3 |
| Gould 3.5 | 4 | 98.0 | 97.3 | 99.3 | 3 | 120.1 | 83.9 | 69.9 | 2 | 56.3 | 58.0 | 103.0 |
| Gould 20 | 4 | 114.4 | 101.8 | 89.0 | 1 | 116.5 | 106.5 | 91.4 | 2 | 41.3 | 73.3 | 177.5 |
| Gulton 6.0 | 4 | 78.1 | 68.6 | 87.8 | 2 | 96.7 | 43.3 | 44.8 | 2 | 61.7 | 35.0 | 56.7 |
| Gulton 20 | 2 | 96.0 | 99.0 | 103.1 | 1 | 116.5 | 39.2 | 33.6 | 3 | 61.4 | 30.0 | 48. |
| Sonotone 5.0 | 4 | 105.4 | 93.8 | 89.0 | 4 | 116.9 | 57.1 | 48.8 | 3 | 80.3 | 45.6 | 56.8 |
| Minimum | | 78.1 | 68.6 | 85.6 | | 96.7 | 39.2 | 33.6 | | 41.3 | 30.0 | 48.9 |
| Average | | 104.0 | 96.2 | 92.6 | | 117.9 | 65.5 | 55.4 | | 63.8 | 46.7 | 79.9 |
| Maximum | | 118.6 | 111.3 | 103.1 | | 131.6 | 106.5 | 91.4 | | 80.3 | 58.0 | 177.5 |




Days of Cycling

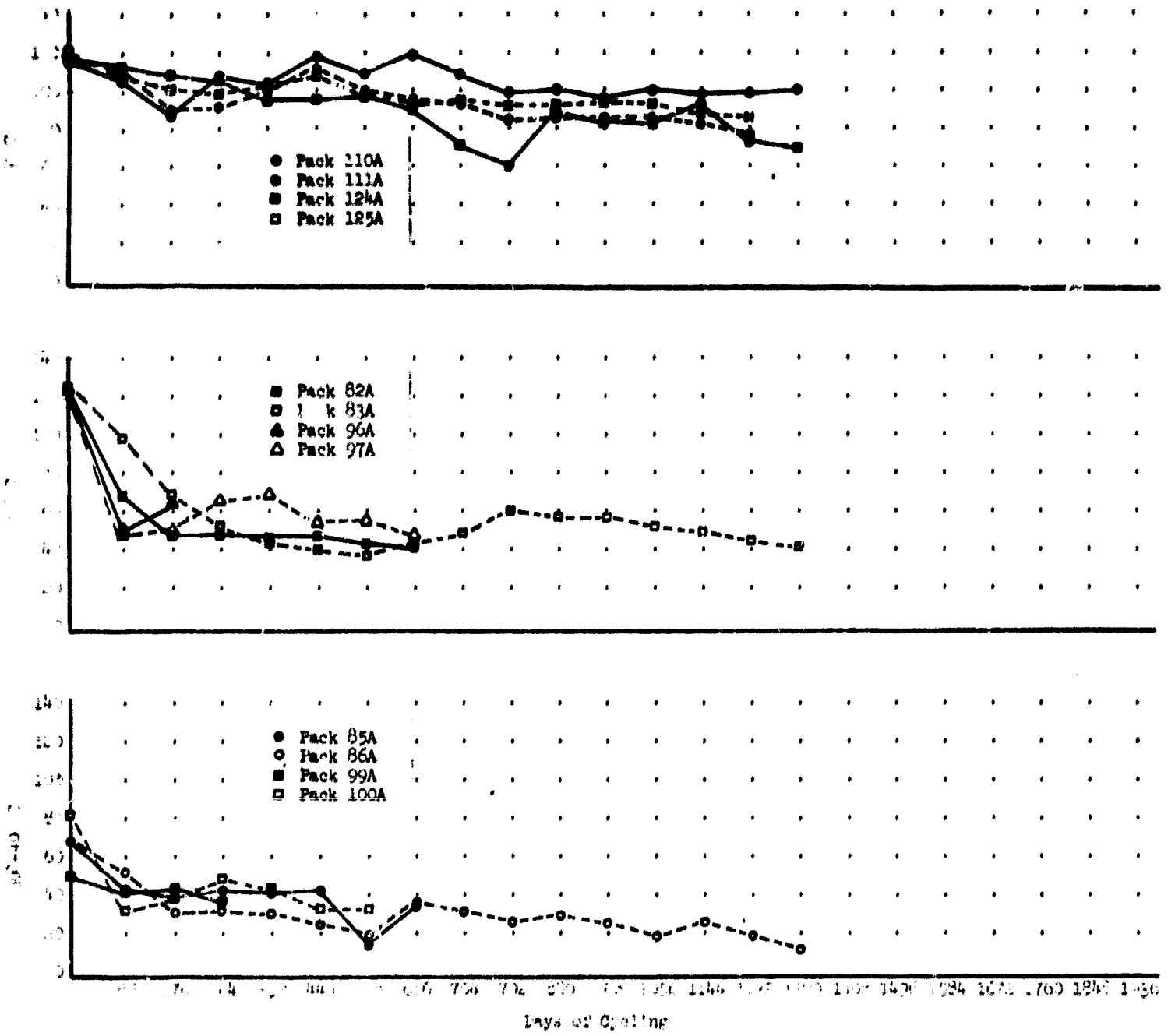
G.E. 3.0 ah

PERFORMANCE AND CAPACITY CHECK CYCLES

(Projected ampere-hours expressed as percent of rated capacity.)

| 4-hr. period | 8-hr. period | Depth of Discharge |
|---|---|---|
| —●— | — —○— — | 1[illegible]% |
| —■— | — —□— — | 2[illegible]% |
| —▲— | — —△— — | 4[illegible]% |

FIGURE 12(A)



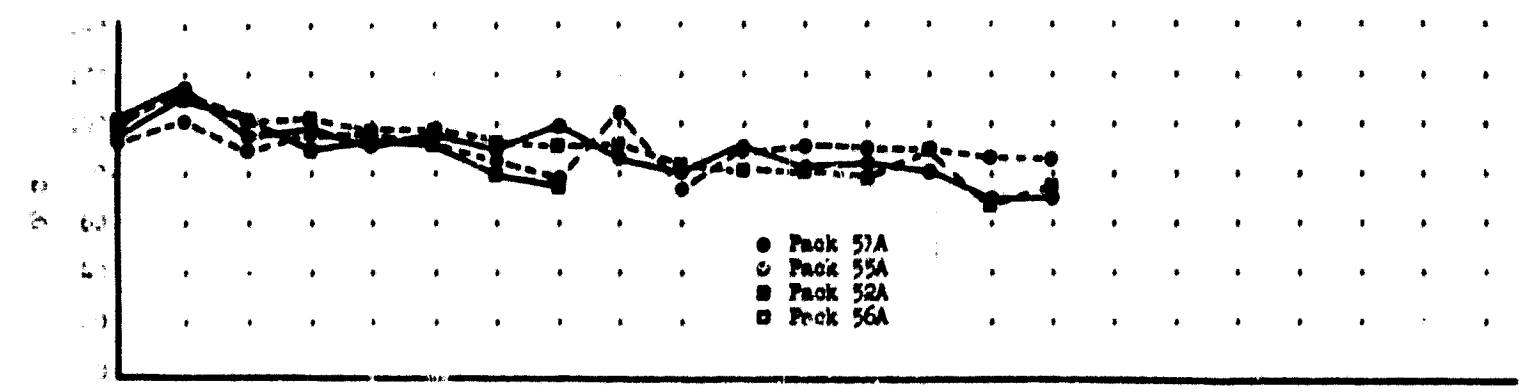

G.E. 12 ah

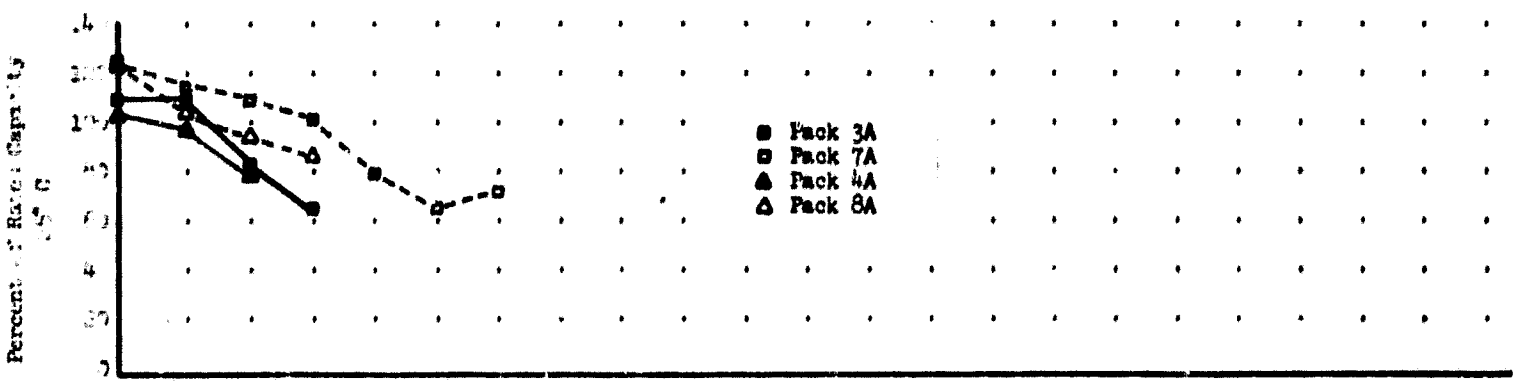
[illegible] AND CAPACITY CHECK CYCLES

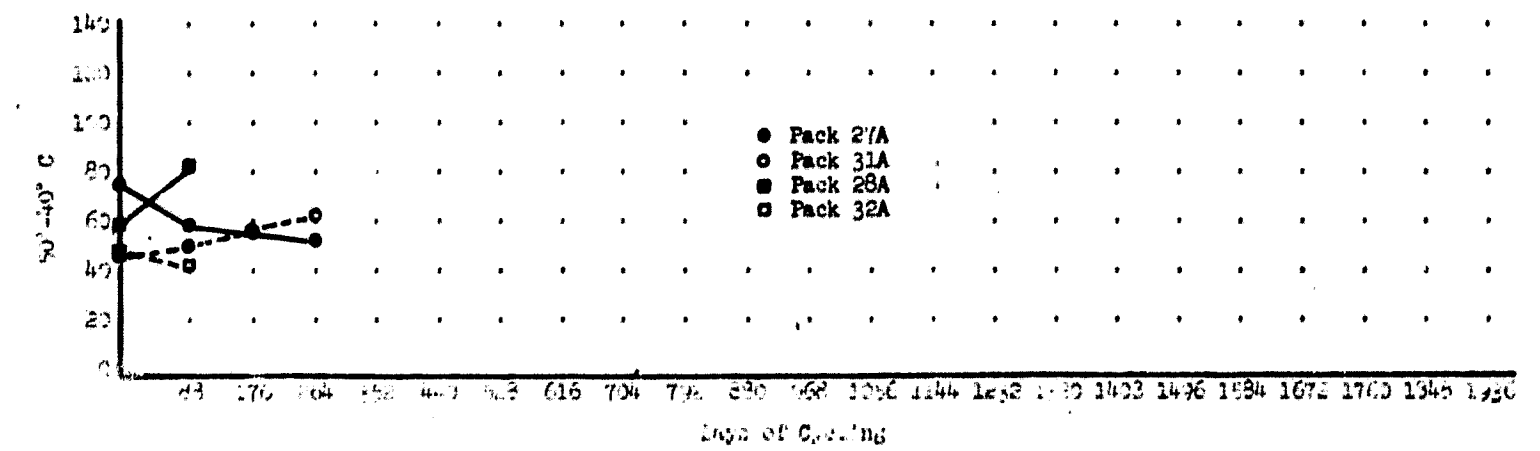
([illegible] ampere-hours expressed as percent of rated capacity)

| [illegible]-hr. period | [illegible]-hr. period | [illegible]th of discharge |
|---|---|---|
| —●— | — —○— — | [illegible]% |
| —■— | — —□— — | [illegible]% |
| —◆— | — —△— — | [illegible]% |

FIGURE 12(B)



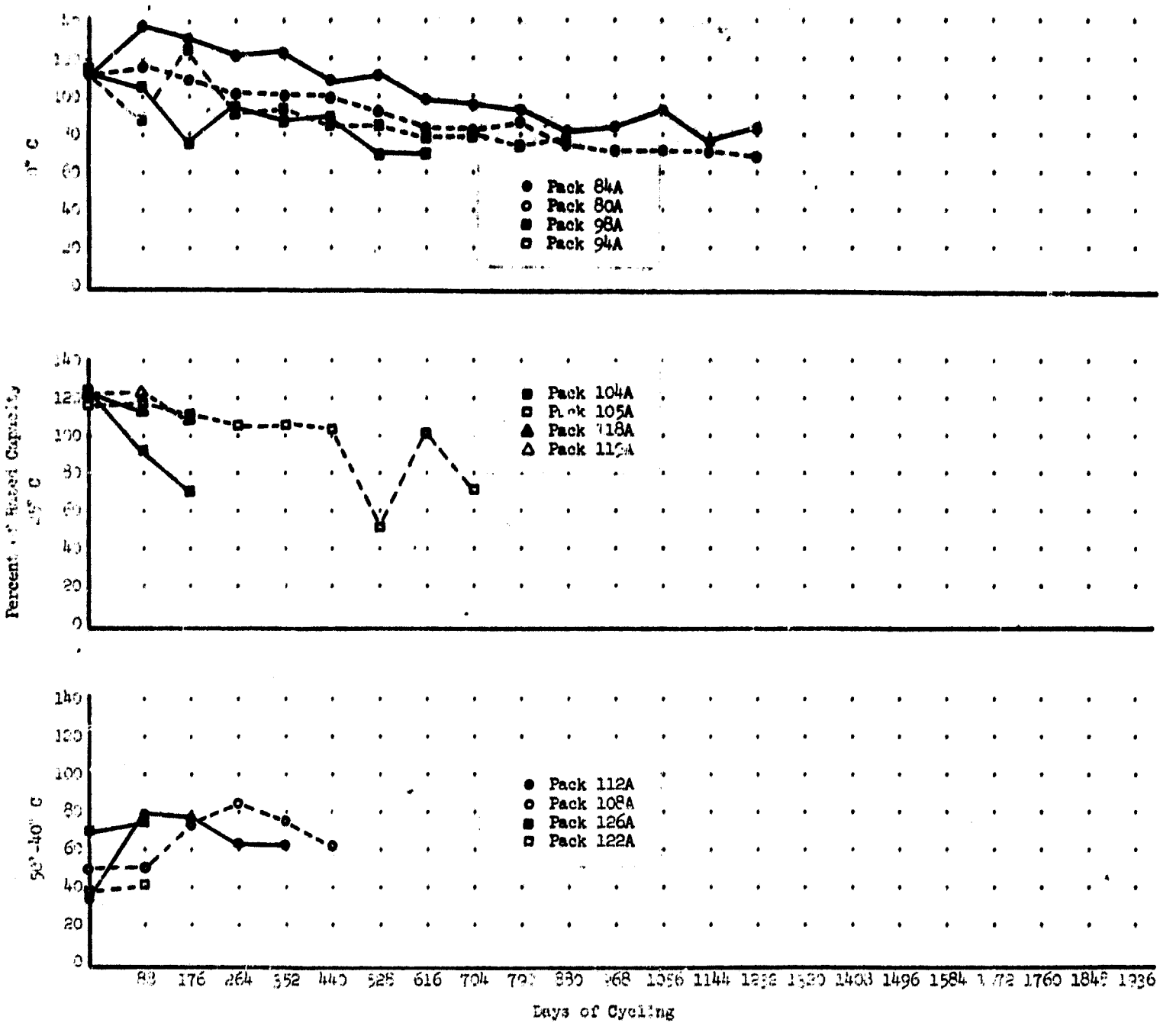

Gould 3.5 ah

PRECONDITIONING AND CAPACITY CHECK CYCLES

(Measured ampere-hours expressed as percent of rated capacity)

| 1.5-hr. period | 3.5-hr. period | Depth of Discharge |
|---|---|---|
| —●— | — —o— — | 15% |
| —●— | — —□— — | 25% |
| —●— | — —△— — | 40% |

FIGURE 12(C)



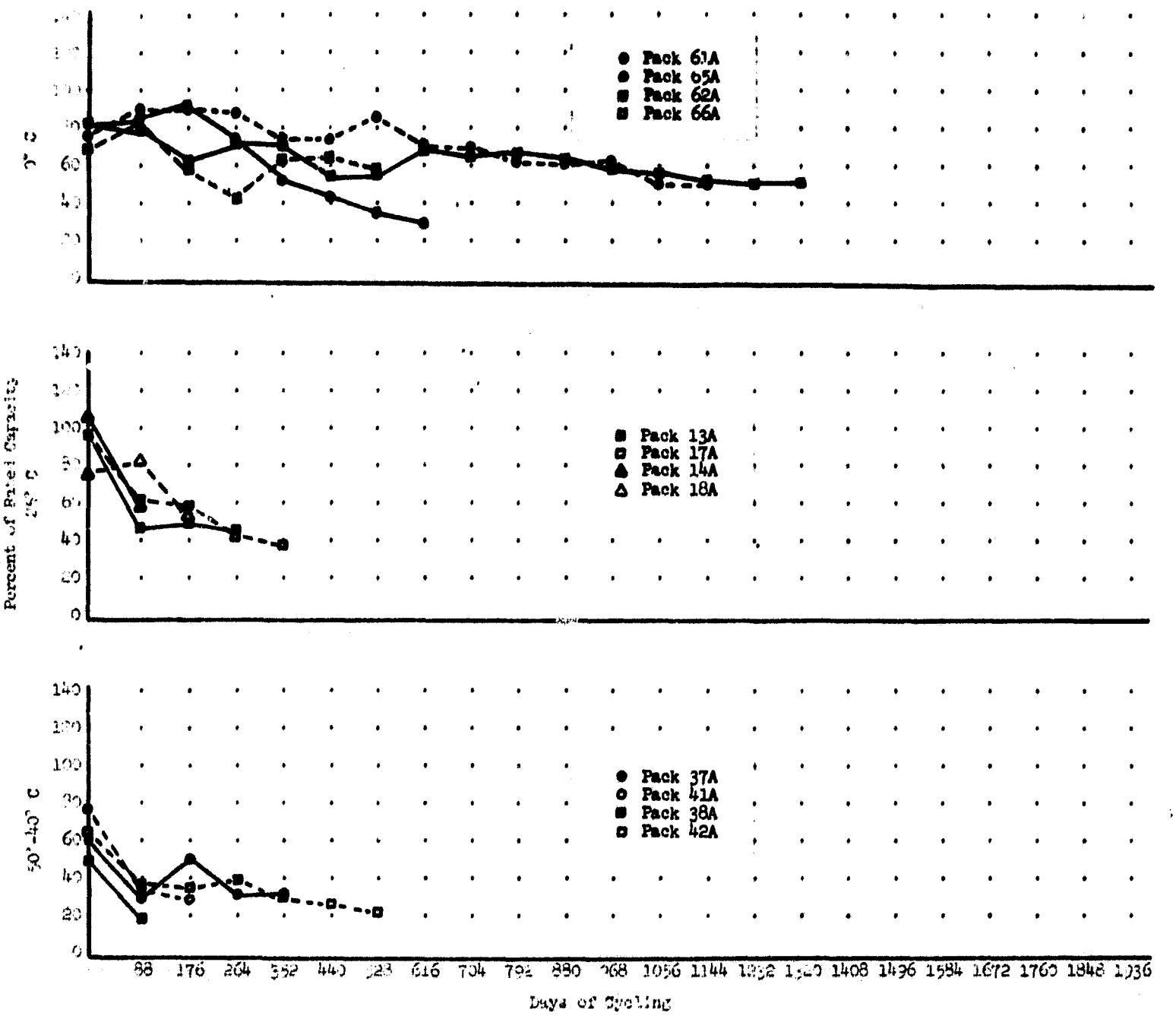

**Gould 20 ah**

PRECONDITIONING AND CAPACITY CHECK CYCLES

(Measured ampere-hours expressed as percent of rated capacity)

| 1.5-hr. period | 3.0-hr. period | Depth of Discharge |
|---|---|---|
| —●— | — —o— — | 15% |
| —■— | — —□— — | 25% |
| —▲— | — —△— — | 40% |

**FIGURE 12(D)**



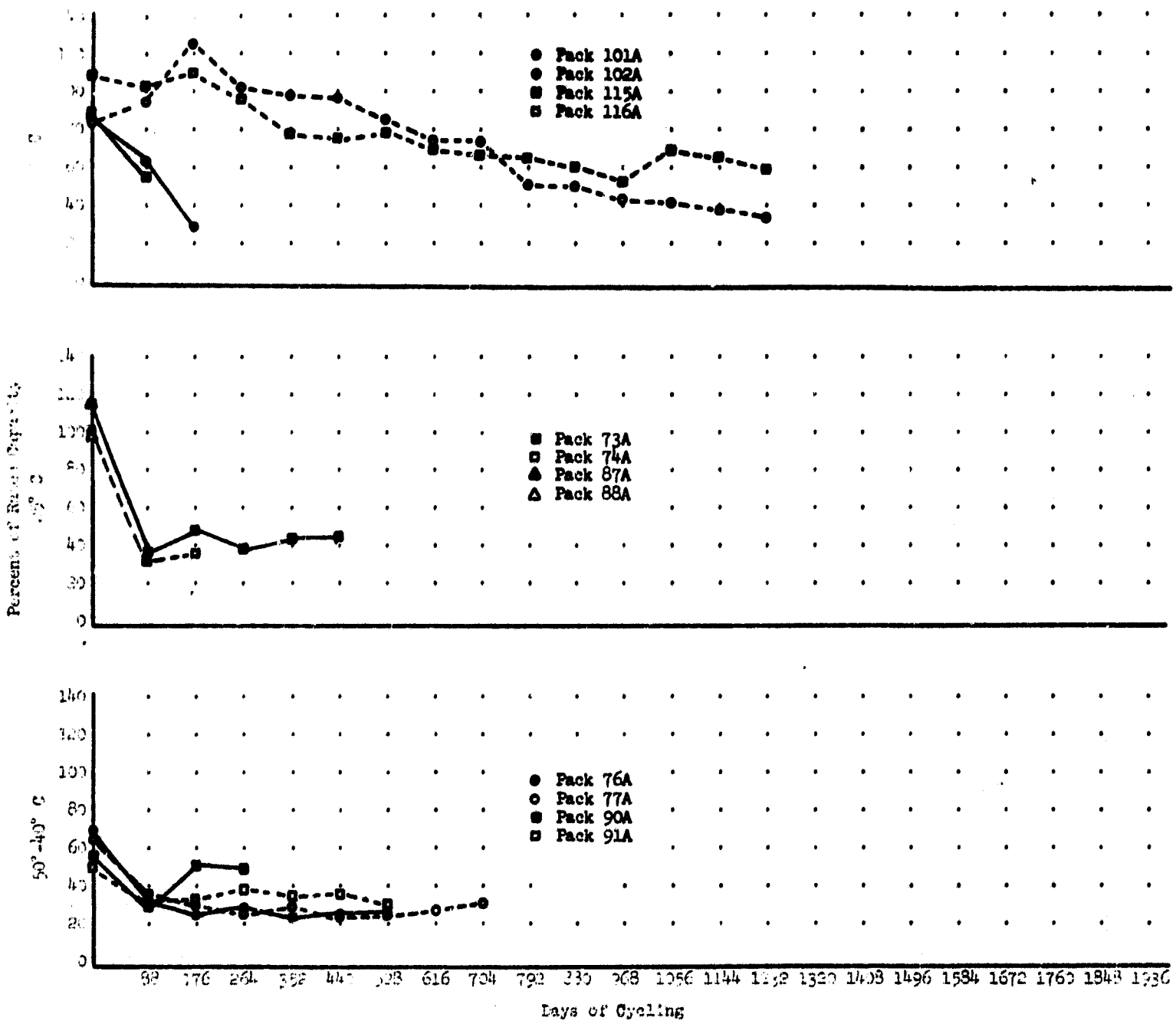

Gulton 6.0 ah

PRECONDITIONING AND CAPACITY CHECK CYCLES

(Measured ampere-hours expressed as percent of rated capacity)

| 1.5-hr. period | 3.0-hr. period | Depth of Discharge |
|---|---|---|
| ●— | —●— | 15% |
| ■— | —■— | 25% |
| ▲— | —▲— | 40% |

FIGURE 12(E)



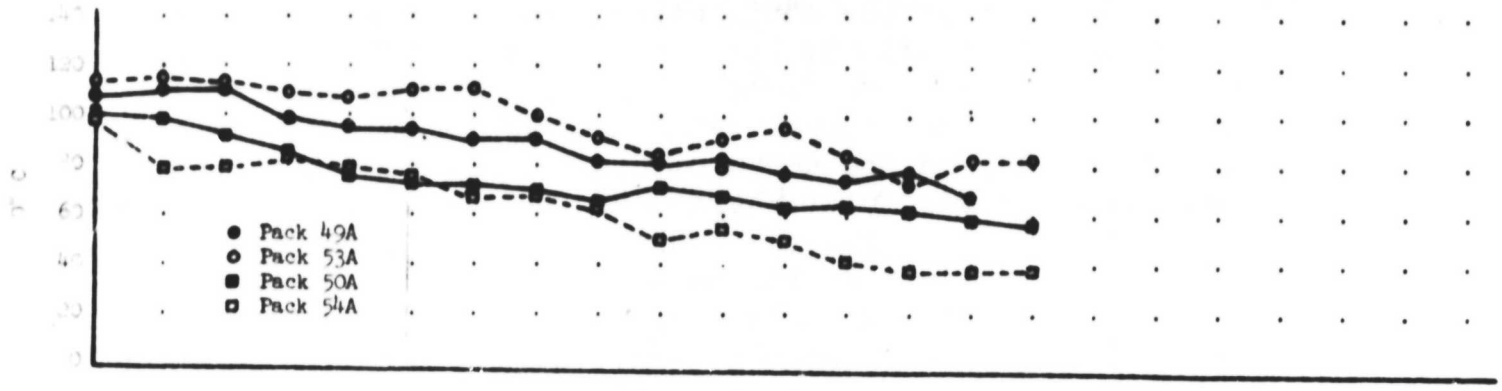

**Gulton 20 ah**

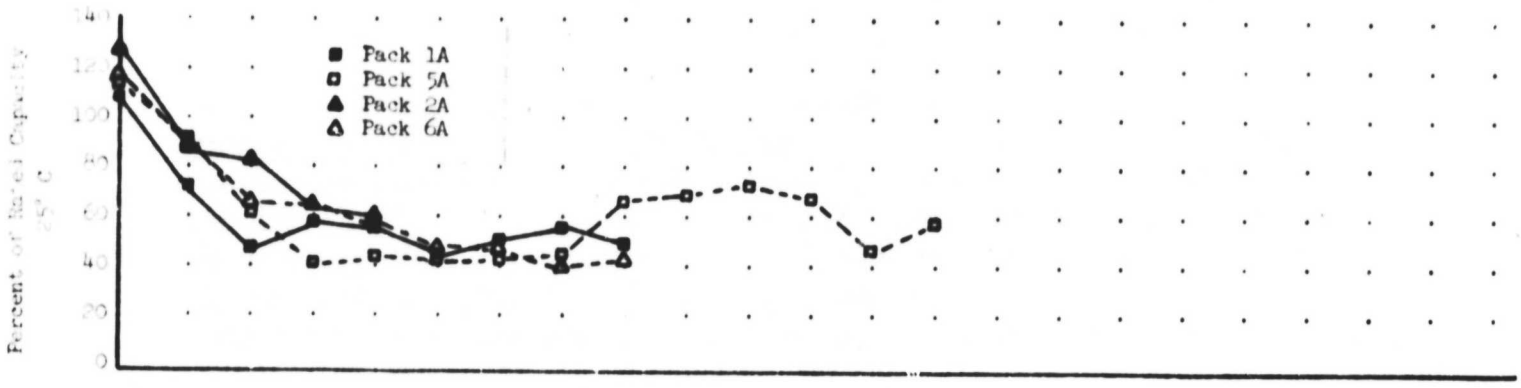
PRECONDITIONING AND CAPACITY CHECK CYCLES

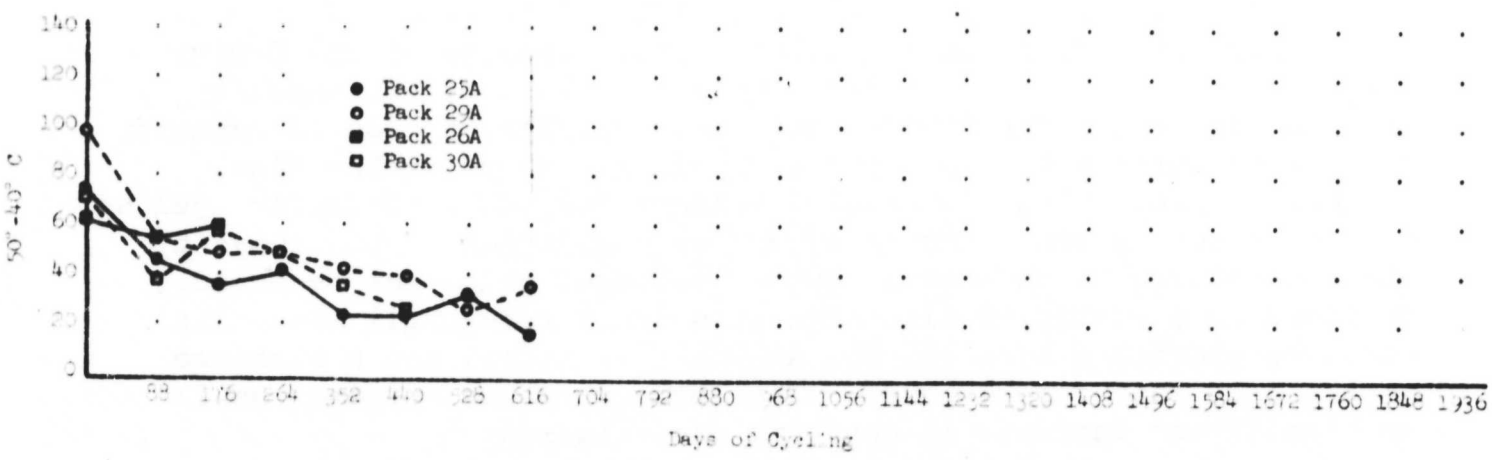
(Measured ampére-hours expressed as percent of rated capacity)

| 1.5-hr. period | 3.0-hr. period | Depth of Discharge |
|---|---|---|
| —●— | — —o— — | 15% |
| —■— | — —□— — | 25% |
| —▲— | — —△— — | 40% |

FIGURE 12(F)




Sonotone 5.0 ah

PRECONDITIONING AND CAPACITY CHECK CYCLES

(Measured ampere-hours expressed as percent of rated capacity)

| 1.5-hr. period | 3.0-hr. period | Depth of Discharge |
|---|---|---|
| —●— | — —o— — | 15% |
| —■— | — —□— — | 25% |
| —▲— | — —△— — | 40% |

FIGURE 12(G)

5. "Memory Effect":

a. Because of the conflicting opinions regarding its nature, we hesitate to attribute test results definitely to memory effect. Briefly, it may be described as a condition wherein a cell, after a number of identical cycles, will drop below one volt as soon as it is discharged beyond the depth of discharge at which it was cycled, even though it was fully charged at the start of the discharge. Where this effect is operating, one would expect the first discharge on a capacity check to yield approximately 15, 25 or 40 percent of the rated capacity, depending on the depth at which the pack was being cycled. Such a result was observed, and was strongly dependent on cell type. It was most prominent at all three temperatures among certain of the Gulton 6.0 ah and 20 ah packs although some packs of other types showed it occasionally at 25° C and 40° C.

b. The first discharge of the capacity check and the subsequent 16-hour charge at c/10 are designed to break the memory effect and otherwise prepare the packs for a truer capacity measurement on the second discharge. Nonetheless, after the first 88 days some packs showed a considerable loss of capacity which was never regained, although the subsequent losses were fairly small. Good examples of this are found among the G.E. 12 ah and Gulton 20 ah packs at 25° C.

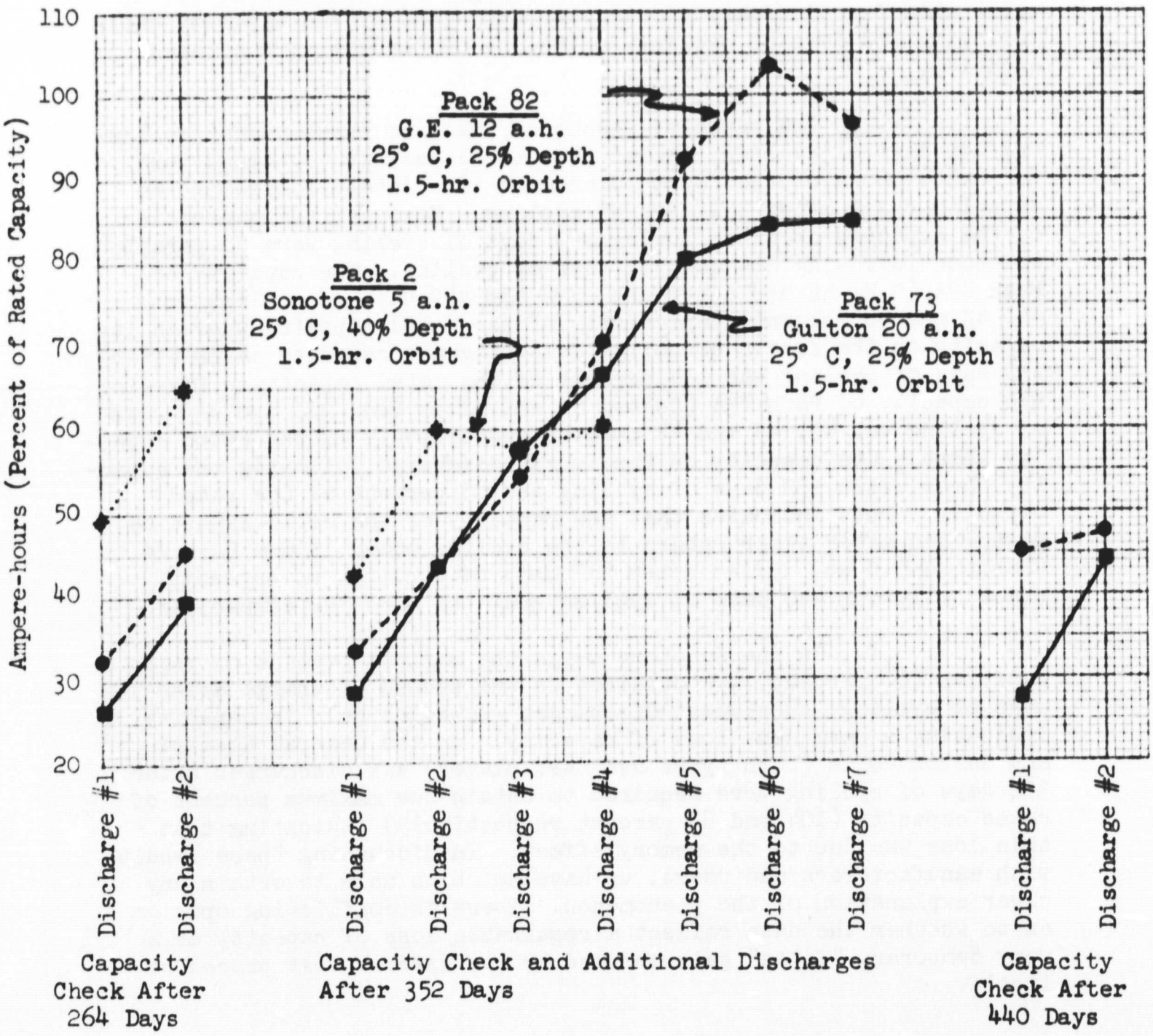
c. In order to obtain additional information, three packs which had shown considerable loss of capacity at 25° C were subjected to a series of cycles similar to those of the capacity checks. The packs first underwent their regular, scheduled capacity check procedures after 352 days of cycling, including the final 48-hour charge. Then, instead of being returned to automatic cycling, the packs were given a series of cycles consisting of the capacity check discharge to the normal cutoff voltage, which was recorded, followed by a continued discharge at a lower rate until the cells could be shorted externally for at least 12 hours, and a recharge at the c/10 rate for 24 hours. This procedure was repeated until no significant increase in capacity was obtained.

d. The three packs selected were Pack 82A (G.E. 12 ah, 25° C, 25 percent depth, 1.5 hours), Pack 73A (Gulton 20 ah, 25° C, 25 percent depth, 1.5 hours), and Pack 2A (Sonotone 5.0 ah, 25° C, 40 percent depth, 1.5 hours). The results are shown in Figure 13. During the four discharges following the capacity check after 352 days of cycling, the capacities of the G.E. and Gulton cells both increased from 43 to 104 and 85 percent respectively, of their rated capacities. However, the previous capacity checks of these cells showed a maximum yield of 66 percent of the rated capacity for the G.E. 12 ah cell on the capacity check following 88 days of cycling, and a maximum yield of 50 percent of the rated capacity

for the Gulton 20 ah cells on the capacity check following 176 days of cycling, The additional discharges of the Sonotone 5.0 ah cells showed no increase in capacity over that of the capacity check following 352 days of cycling, which was 60 percent of the rated capacity.

e. The capacity checks of the same three packs, following 440 days of cycling, showed that the capacities obtained were far below those of the fourth discharge immediately following the capacity check after 352 days of cycling. However, the capacities of the capacity check following 440 days of cycling were comparable to those following 264 and 352 days of cycling. The capacity of Pack 82A (G.E. 12 ah) after 264, 352 and 440 days of cycling was 46, 43 and 48 percent respectively of the rated capacity whereas its capacity on the fourth discharge following the capacity check after 352 days of cycling was 104 percent of the rated capacity. Likewise, the capacity of Pack 73A (Gulton 20 ah) after 264, 352 and 440 days of cycling was 40, 43 and 44 percent respectively of the rated capacity whereas its capacity on the fourth discharge following the capacity check after 352 days of cycling was 85 percent of the rated capacity. This indicates that the capacity of the cells cannot be maintained after their return to the cycling mode. Since Pack 2A (Sonotone 5.0 ah) failed after 417 days of cycling, no capacity check following 440 days of cycling could be made for comparison.

f. On the Sonotone cells the maximum percent of rated capacity (60 percent) was obtained on the second discharge after 352 days of cycling; subsequent discharges showed no gain in capacity, indicating a permanent loss of capacity. On the General Electric and Gulton cells (both types use SAFT plates) six discharges after 352 days of cycling were required to obtain the maximum percent of rated capacity (104 and 85 percent respectively) indicating that this loss was due to the memory effect. In discussing these results with manufacturers and users, we have not been able to obtain any clear explanation of the phenomenon. There is conflicting opinion as to whether the data reflect a regainable loss of capacity or a very temporary "false" gain induced by the special test procedure itself.




INCREASE IN CAPACITIES OF SUCCESSIVE DISCHARGES
FOLLOWING 264, 352 AND 440 DAYS OF CYCLING

FIGURE 13

## V. TEST FACILITIES

A. Environmental Chambers: Ambient test temperature conditions were obtained with the following equipment:

1. -20° C. A 12 cubic foot chamber manufactured by General Thermodynamics, Inc., Model UCH 322 C-B, temperature controls accurate to within ± 1.5° C.

2. 0° C. A 27 cubic foot chamber manufactured by the A. Webber Engineering Corporation, Model WF-27-40, temperature controls accurate to within ± 1.5° C.

3. 25° C. Packs cycling at 25° C are located in an air conditioned room with other temperature critical equipment. The temperature is maintained at 25 ± 2° C.

4. 40° C. A 27 cubic foot chamber manufactured by Tenney Engineering, Inc., Model UF-40240, temperature controls accurate to within ± 1.5° C.

5. Several small chambers are used as required for additional packs and for any special temperature requirements. They range in size from 1.5 to 2.5 cubic feet and have a temperature range of -75° C to 175° C.

B. Charge and Discharge Control Units:

1. Each cell pack is connected to its own, independent, solid state current limiting charging unit. These units control the charge rates and voltage limits by regulating the current supplied by a 28 VDC generator which is common to all units. They also discharge the packs by a relay switching system which changes the current lead connections within the units. Each has two ammeters rated at ± 1 percent accuracy for visual monitoring of the charge and discharge currents, and three separate controls for setting the currents and voltage limit at the desired values. A 3-position switch selects between continuous charge, continuous discharge, and automatic cycling operation. Automatic cycling is controlled by a stepping relay which receives a pulse for each minute from a digital clock. The stepping relay is wired for both the 1.5-hour and 3-hour orbits. Each unit is connected to the corresponding output for its cycle period. The reference voltage for the voltage limiting circuit in each unit is supplied by using a voltage divider in series with a constant current circuit.

2. Photograph 2 shows a front view of several charge-discharge units.

C. Upper and Lower Voltage Limit Monitoring System.

1. Each pack is connected tc its own lower limit voltmeter which sets off an alarm common to the system and turns on an identifying light for the particular pack when the terminal voltage of the pack falls below a preset limit. Photograph 3 is a picture of the lower voltage limit monitoring system.

2. An additional system is used to scan each individual cell voltage. When the voltage of any cell is found to be outside the preset upper or lower limits, the system automatically sets off the alarm and the identifying light in the lower voltage limit monitoring system and also disconnects the current leads of that pack by de-energizing a relay. The system includes a 900-point modified crossbar scanner which scans continuously at a rate of 330 points per minute, so that each cell is scanned every 2 minutes. Voltages are measured by a DC to frequency converter and a frequency counter. The scanning system is shown in Photograph 4.

D. Data Logging System.

1. Brief Summary.

a. Recordings are made by means of a data logging system (Photograph 5) obtained from Gulf Aerospace Corporation. All monitoring leads from a given pack of cells are scanned, converted to digital form and fed to the Tally Mark 45P paper tape punch and programmed reader. The system permits the current, pack terminal voltage, all cell voltages and thermocouple voltages for a given pack to be read and punched out within less than 4 seconds. An additional switching arrangement permits recording up to six 10-cell packs and 12 5-cell packs at one time.

2. Technical Description.

a. This system is designed to record data from 30 data channels by sampling and scanning the input voltages. The data is converted to binary code by a precision amplifier and a high speed analog to digital converter and is presented serially by character to the paper tape punch for storage of the data. Figure 14 is a block diagram of the data logging system.

b. The system measurements are either timed and controlled by the system's digital clock, or manually controlled by the operator. Additional features of the system provide for a typed report of the stored data.

c. The system has 30 input channels. Of these, channels 1 to 10 have a full scale input of 10 volts and measure cell voltages.

Channels 11 and 13 have a full scale range of 20 volts and measure the total pack voltages. Channels 12 and 14 have a full scale range of 100 millivolts and measure the voltage across 100 millivolt current shunts.

d. All of these inputs, 1 to 14, are sample and hold type inputs. They are sampled simultaneously for 400 milliseconds. The attenuated input signal voltages, all of which are normalized to 100 millivolts full scale, are stored on high quality capacitors. The scanner then sequentially scans these capacitors for data readout. This technique is used to eliminate any difference in time between the first 14 input readings. The accuracy of these channels is ± 0.25 percent of full scale reading.

e. Channel 15 is used for battery pack identification. Another instrument, which provides selection for monitoring a given pack from a group of packs, provides an output from which the particular pack selected can be identified. This output voltage is read on channel 15 as the position identifying the pack. The operator or project leader correlates these readings with specific packs being tested.

f. Channels 16 through 30 are low level input channels (± 10 millivolts full scale) designed to monitor thermocouple inputs with an accuracy of ± 1 percent of full scale. These channels have a maximum common mode voltage that can exist between the signal and the system ground of ± 10 volts. If the common mode voltage exceeds this value, accurate readings can no longer be taken. (Common mode voltages of over ± 20 volts may damage the differential amplifier.)

g. Cycle time for this system is less than 4 seconds for all 30 channels. The readout system, a Tally Mark 45P, is capable of receiving data from the analog to digital converter, from a prepunched paper tape, or from the Selectric typewriter by manual input and may be programmed to print out the data, off line, in any desired format.

3. System Operation.

a. During the scanning process each channel in turn is routed to the input of a high impedance differential amplifier, the gain of which is automatically switched between 100 (the amount used for the high level channels) and 1000 (the amount required for the low level channels). The sensing for the gain change is supplied by the relay drivers. Provisions are made to eliminate amplifier drift while sampling voltage across the storage capacitors. The output of the amplifier is applied through a low pass filter at the input of the analog to digital converter. The analog to digital converter is then given a command to read.

b. The analog to digital converter converts the analog signal to a binary coded decimal signal. A serializer sequentially sends one digit at a time from the output of the clock or from the analog to digital converter to the perforator driver. The zero generator and the parity generator maintain the proper digital format for punching paper tape and operating the Selectric typewriter in the Tally Mark 45F system. The punched-paper-tape code is compatible with IBM binary coded decimal code (Hollerith).

4. System Controls.

a. The 30-position data scanner has several modes of operation. Mode switch may be set to continuous cycling, preset cycle, single cycle, single step, and manual select. In the continuous cycling position the scanner continues to sample the data at a rate determined by the digital clock. In the preset cycle position the scanner takes a sample of the data at a time determined by the preset time selector. In the single cycle position the scanner samples the data once each time the step/cycle push button is depressed. In the single step position the scanner is advanced one channel at a time by depressing the step/cycle push button switch. In the manual select position the scanner remains at the channel selected by the manual select switches. When in either of the two manual modes a reading is taken by pushing the print button. The scanner has two front panel displays, one for channel number and one for voltage. All system functions are timed by a unijunction oscillator and are controlled by logic circuits in the scanner assembly.

E. Central Wiring Panel.

1. All electrical connections are made through a centrally located wiring panel which houses the current shunts and a plug-in panel. Photograph 6 shows the front view of the central wiring panel.

F. Pack Selector Switch.

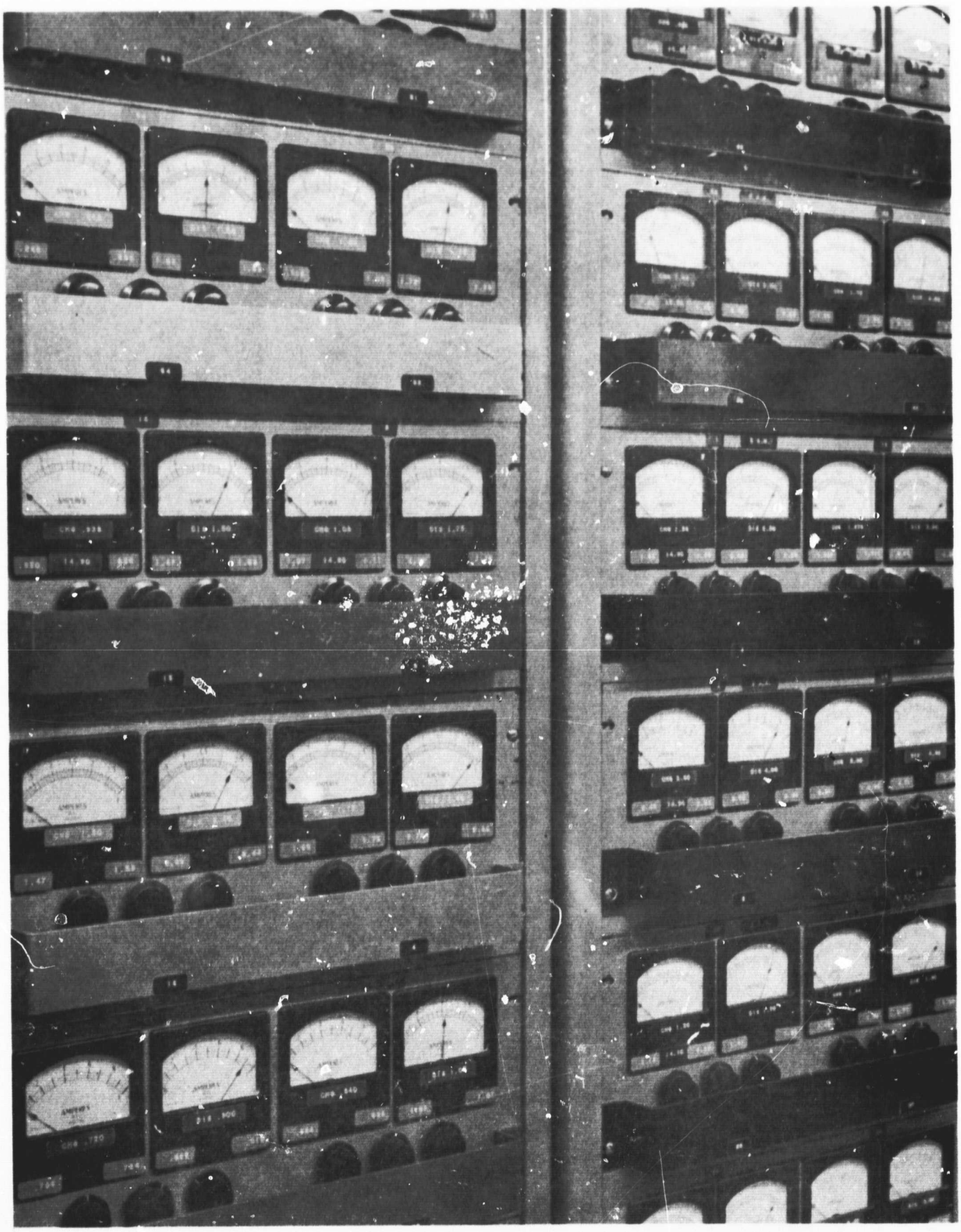
1. Up to six 10-cell packs and 12 5-cell packs may be plugged into a selector system from the central wiring panel. Through reed relays operated by a selector switch, any of these packs can then be connected to the input of the data logging system. This arrangement allows all currents and cell and thermocouple voltages for all 18 packs to be recorded by the data logging system within 48 seconds.

2. The switching system also provides a voltage which identifies the selected position and which is automatically recorded as part of the data for the pack selected.

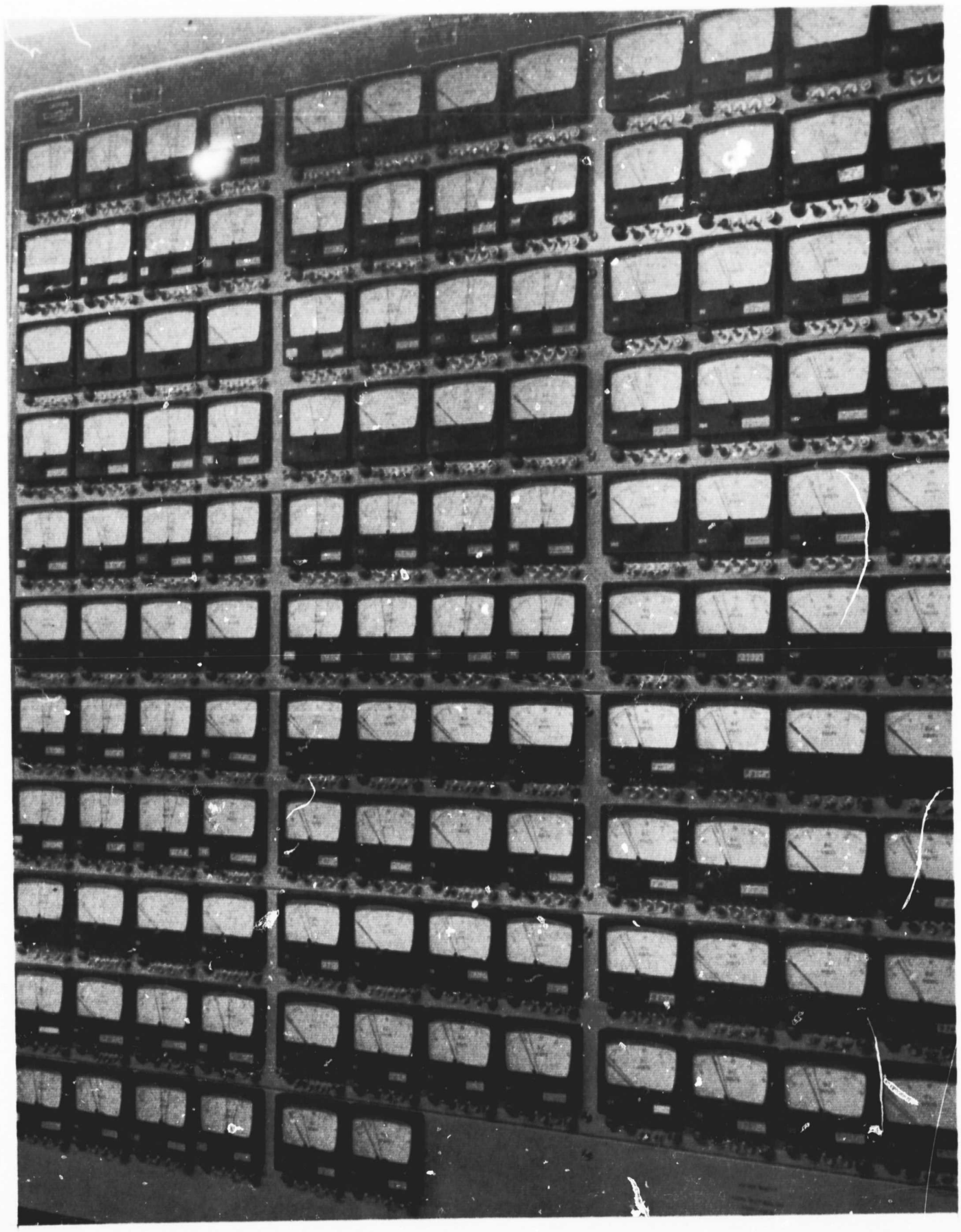
3. Photograph 4 shows the pack selector switch located on top of the data logging system.

G. Block Diagram of Entire Test Setup: Figure 15 shows the arrangement from the packs at each of the three ambient temperatures to the central wiring panel. Leads from the central wiring panel connect all packs and/or cells to the charge-discharge units and the 28 volt DC source, the circuit relay switching system, the voltage limiting monitoring system and the data logging system.

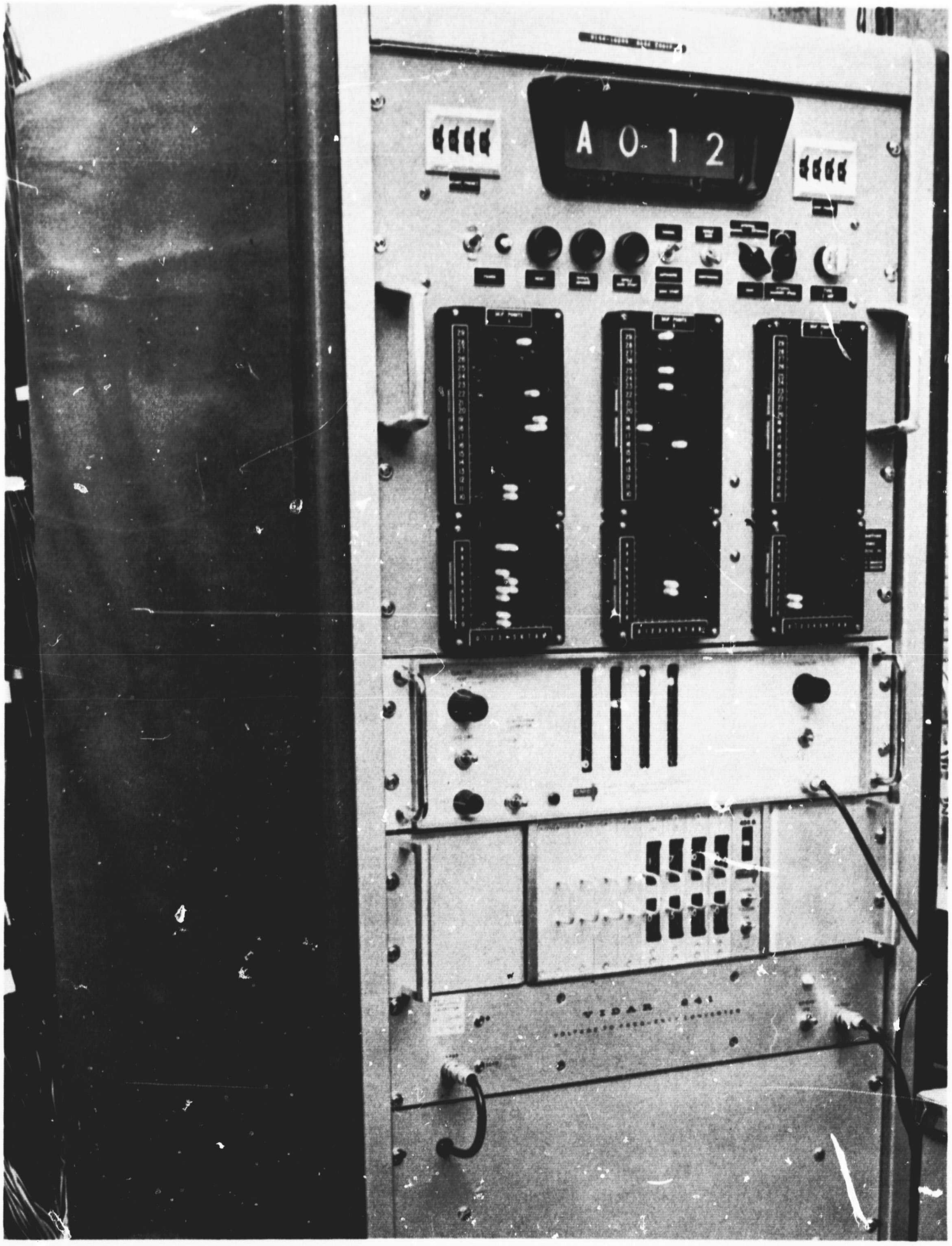
H. Photograph of Test Area: Photograph 7 shows the overall arrangement of the test equipment described in paragraphs V.B. through V.G.



Several Charge and Discharge Control Units
PHOTOGRAPH 2

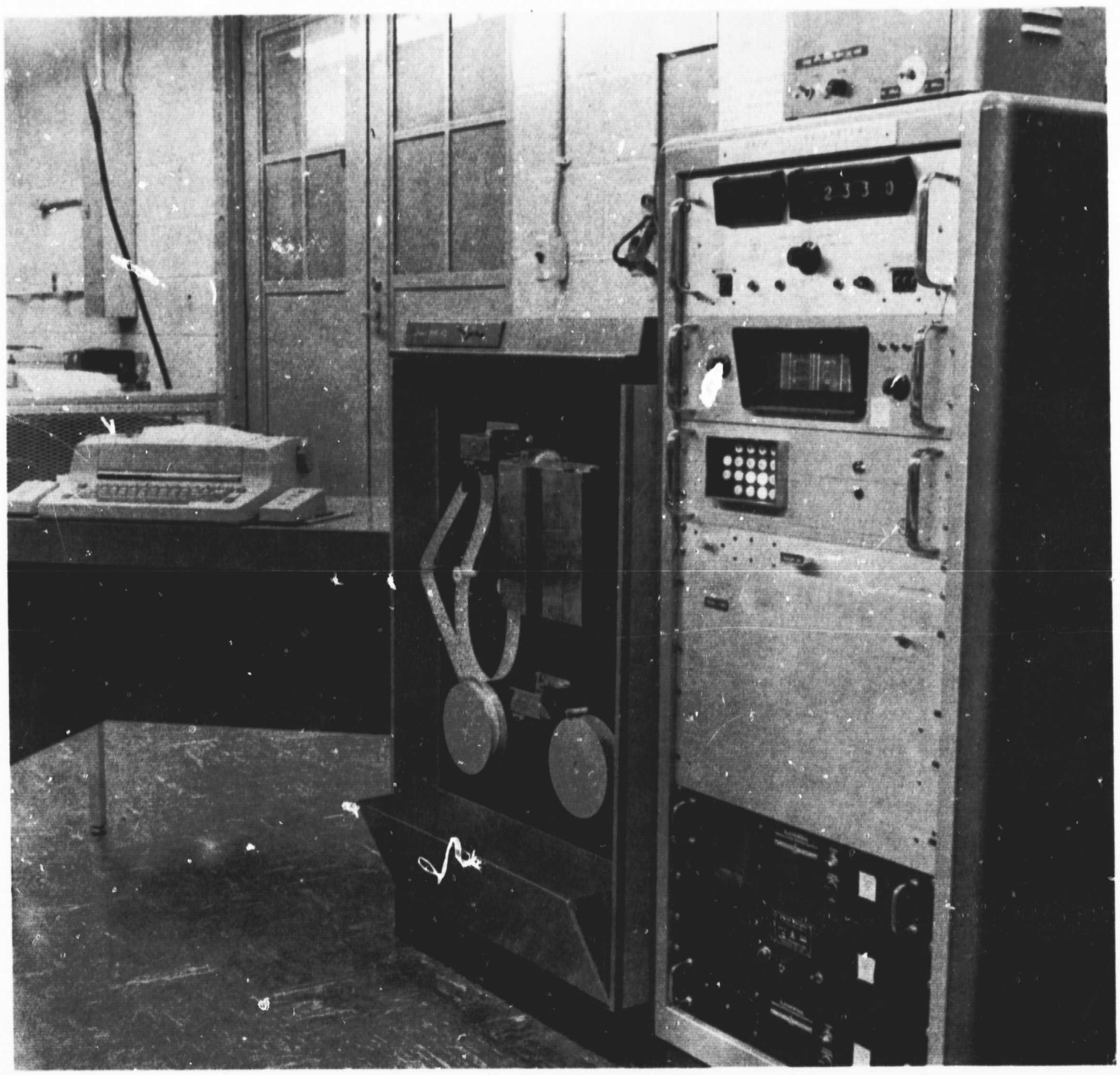


Pack Voltage Monitoring Panel
PHOTOGRAPH 3



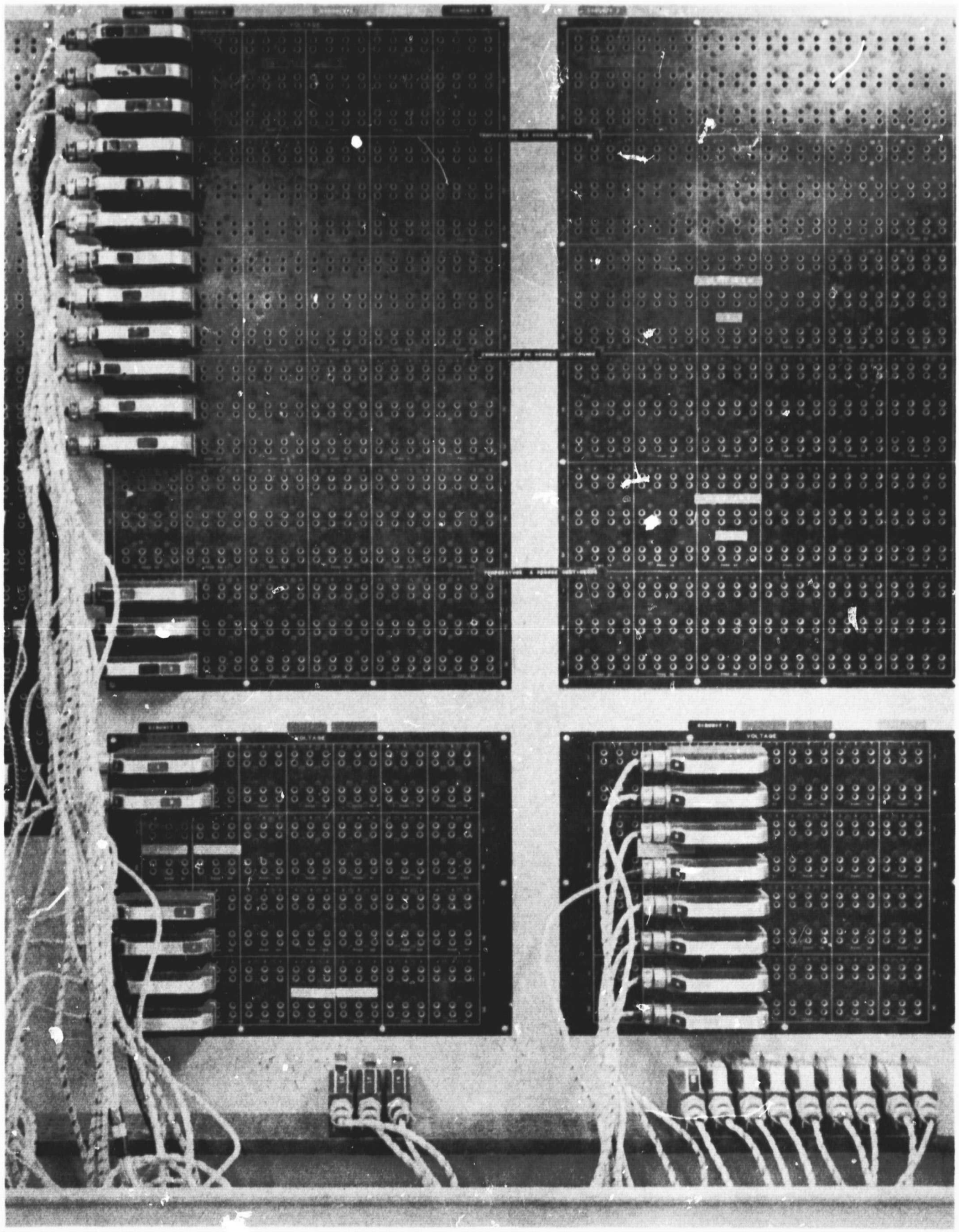

Individual Cell Voltage Scanning System

PHOTOGRAPH 4



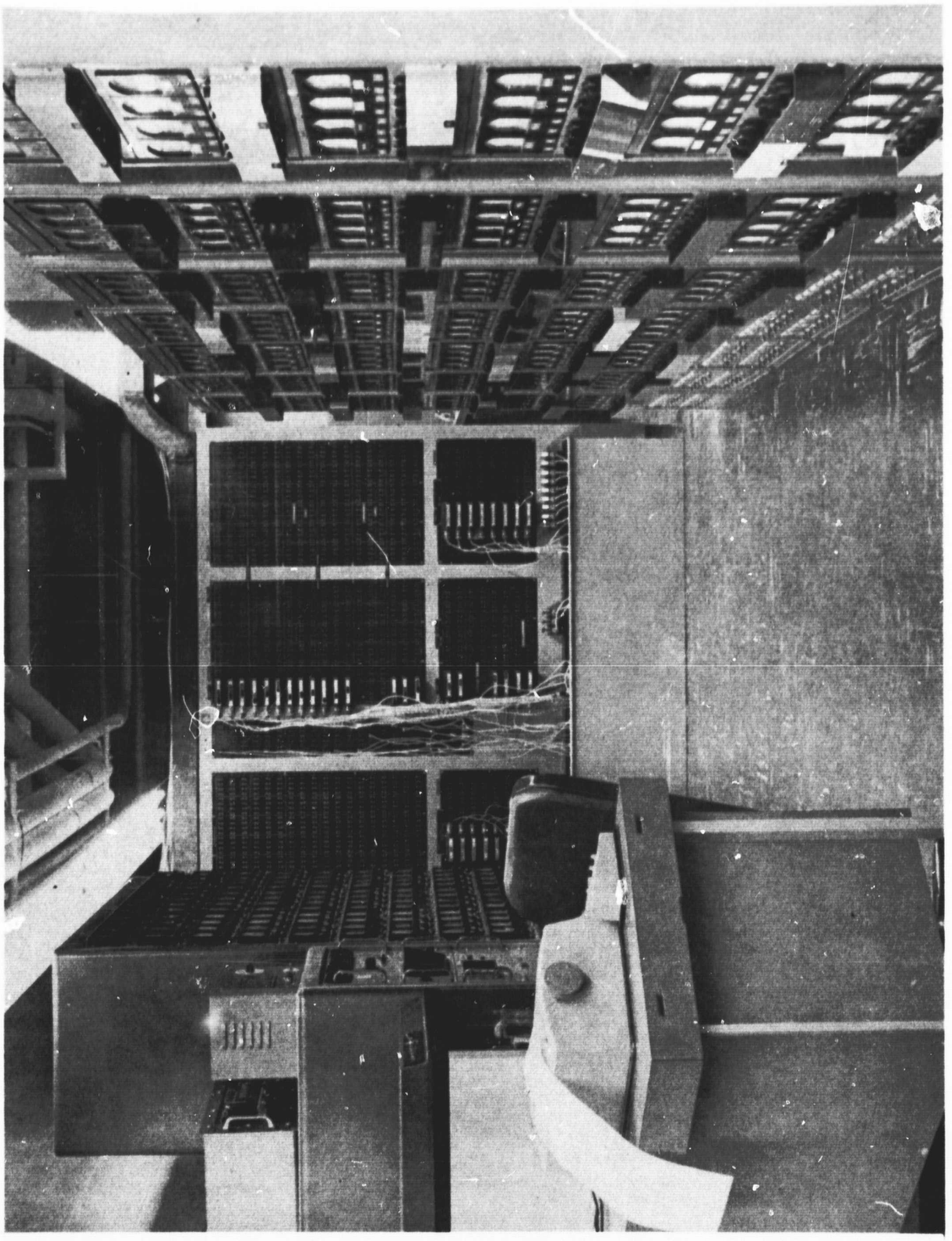

Data Logging System

PHOTOGRAPH 5

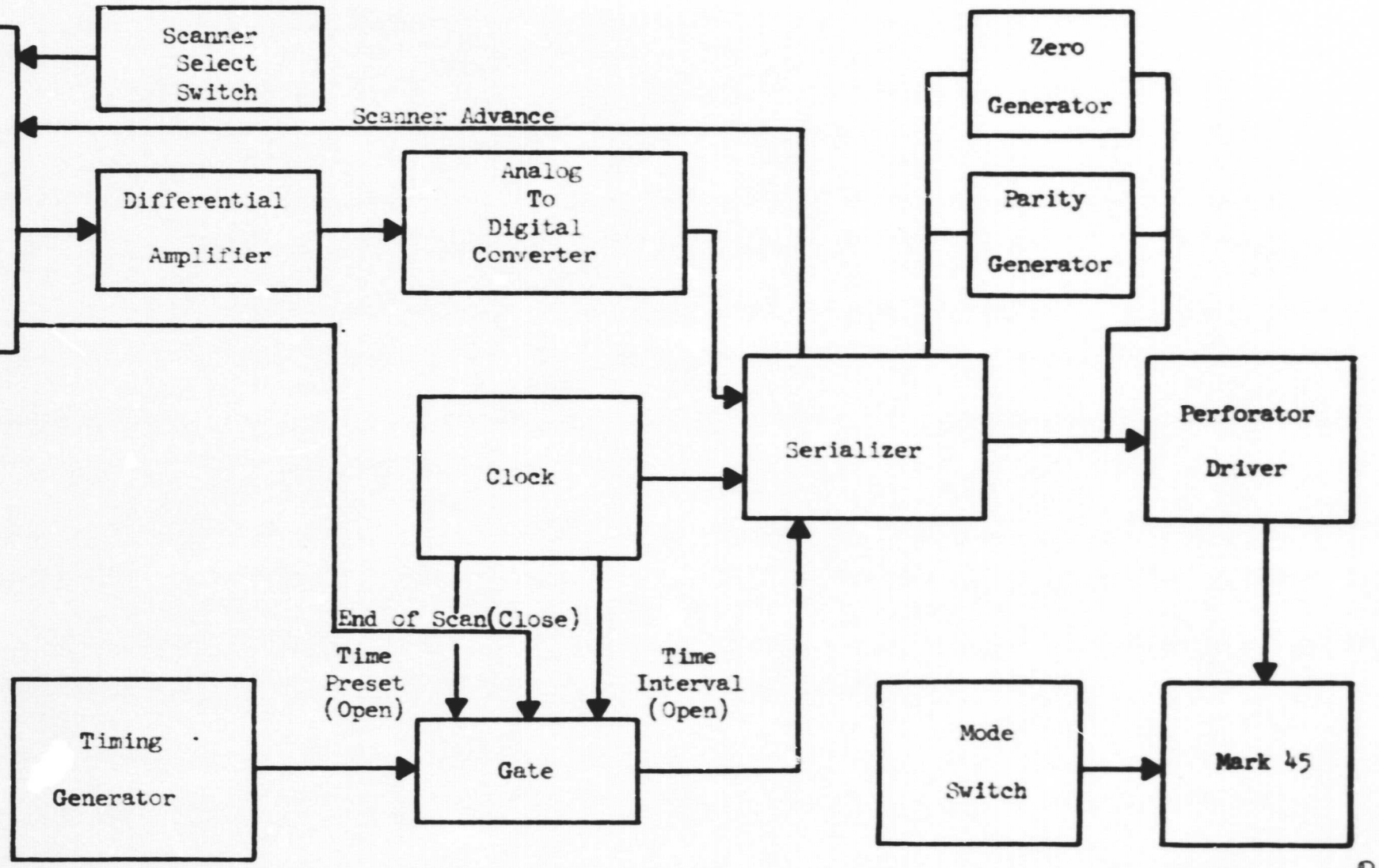


Portion of Central Wiring Panel

PHOTOGRAPH 6



Test Area
PHOTOGRAPH 7

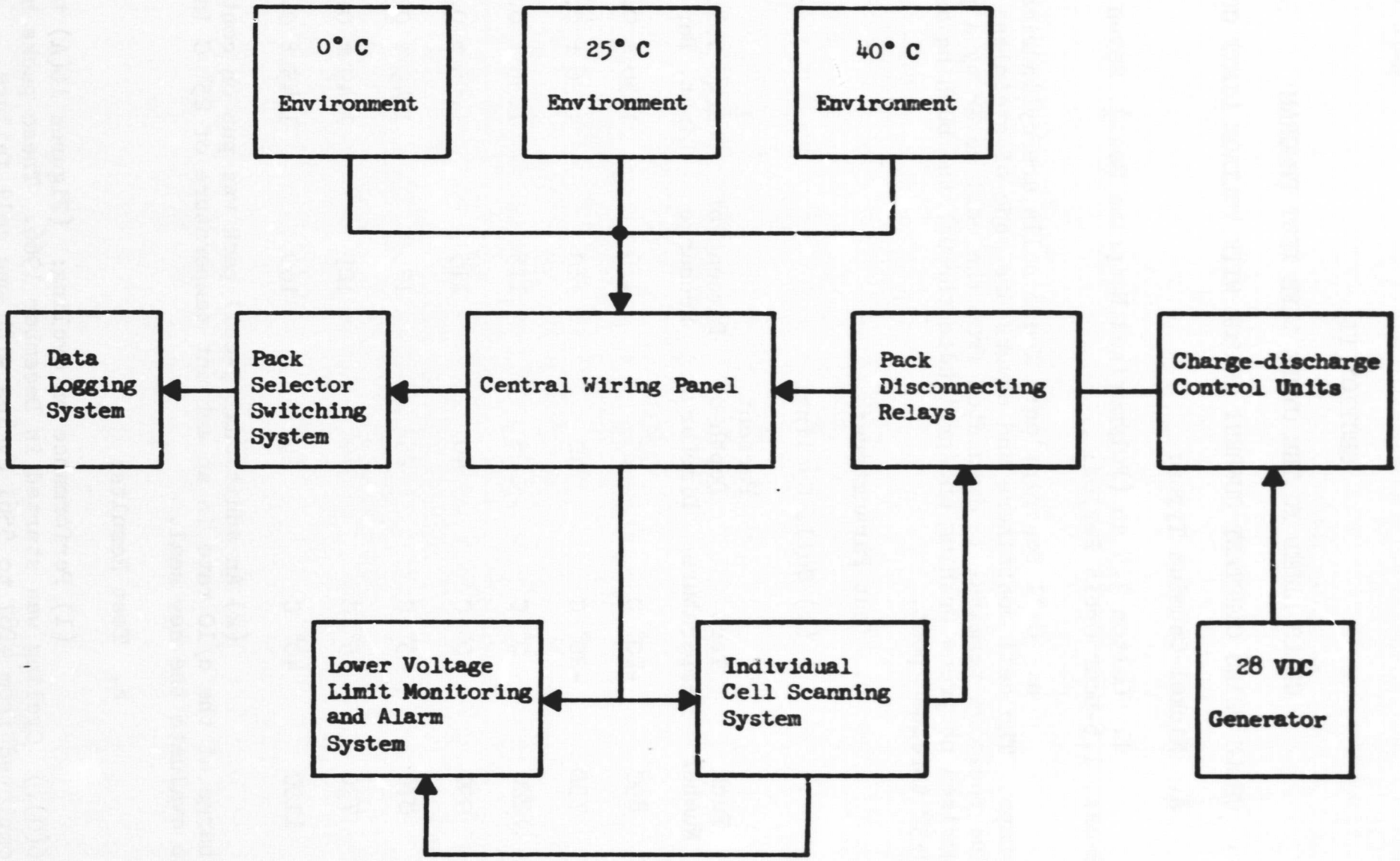



Block Diagram of Data Logging System

**FIGURE 14**



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Block Diagram of Test Setup
FIGURE 15

## SECTION II

## CELLS ADDED TO THE CYCLE LIFE TEST PROGRAM

### I. CELLS USING CONSTANT CURRENT CHARGE WITH VOLTAGE LIMIT CONTROL

A. Nickel-Cadmium Types:

1. Gulton 3.5 ah (Polymerized Neoprene Seal), Seven 5-cell Packs, 1.5-hour Orbit Period:

a. Cell Description: These cells are cylindrical in shape. The cell containers and covers are made of stainless steel. The positive terminal is insulated from the cell cover by a polymerized neoprene bushing and protrudes through the bushing as a 8-32 threaded post.

b. Test Parameters:

(1) Cells Cycling:

| Pack Number | Test Temperature | Percent Depth of Discharge | Percent of Recharge | Charge Voltage Limit, Per Cell |
|---|---|---|---|---|
| 89C | -20° C | 25 | 110 | 1.56 ± 0.03 |
| 75D | -20° C | 40 | 110 | 1.56 ± 0.03 |
| 122C | 0° C | 25 | 115 | 1.55 ± 0.03 |
| 99C | 0° C | 40 | 115 | 1.55 ± 0.03 |
| 87C | 25° C | 25 | 125 | 1.49 ± 0.03 |
| 73C | 25° C | 40 | 125 | 1.49 ± 0.03 |
| 112C | 40° C | 25 | 160 | 1.45 ± 0.03 |

(2) An additional 5-cell pack was put on continuous charge at the c/10 rate in an ambient temperature of 25° C in order to evaluate the new seal.

c. Test Results:

(1) Performance on cycling: (Figures 16(A) through 16(G).) Cycling was started in December 1966. These packs have completed from 4287 to 5561 cycles with one cell failure.

(a) The end-of-discharge voltages of the cells cycling at 40° C were much lower than those cycling at the lower temperatures.

(b) The one cell that failed was cycling at -20° C. This cell showed signs of separator deterioration and negative material migration. The cell container was distorted by high internal pressures but there were no signs of leakage.

(c) The one 5-cell pack that was put on continuous charge has not shown any signs of high pressure or leakage.

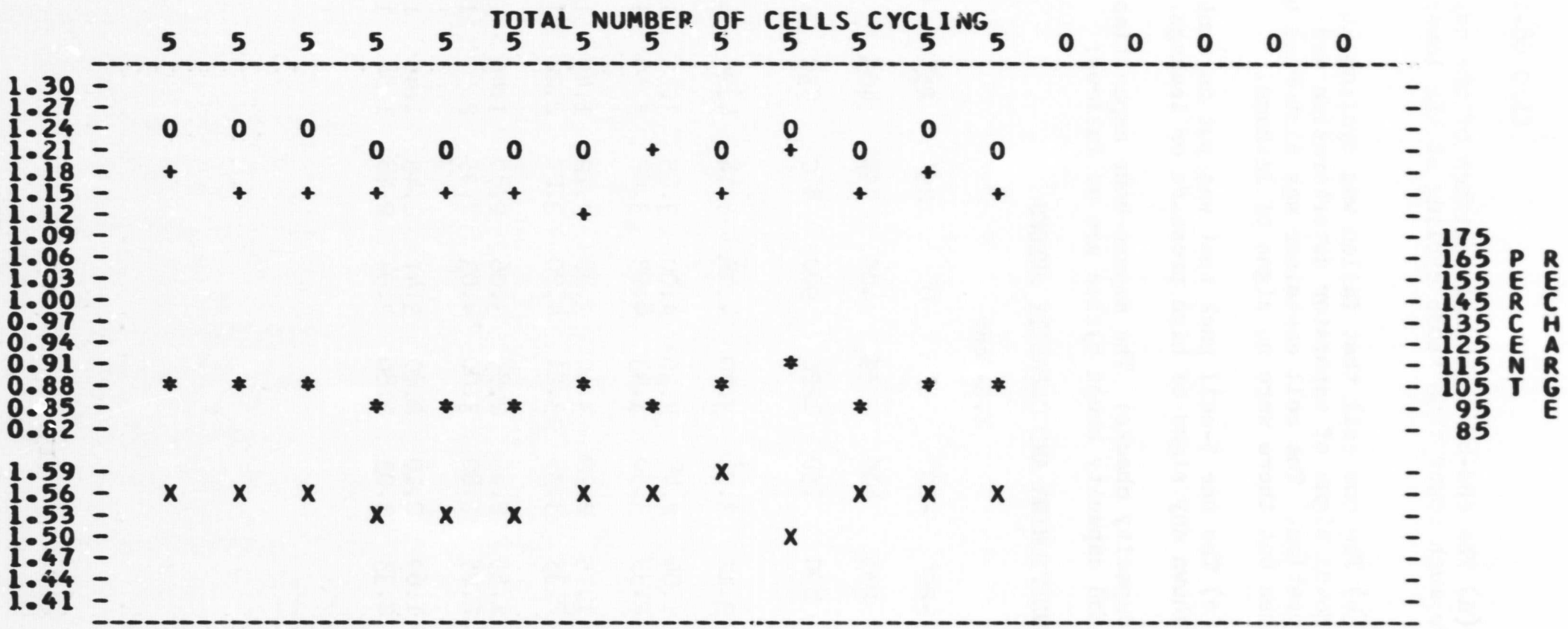
(2) Capacity checks: The ampere-hour capacities on the preconditioning and capacity check cycles are as follows:

PRECONDITIONING AND CAPACITY CHECKS

| Orbit Period | | 1.5-hour | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Temperature | | -20° | -20° | 0° | 0° | 25° | 25° | 40° |
| Depth of Discharge | | 25% | 40% | 25% | 40% | 25% | 40% | 25% |
| Pack Number | | 89C | 75D | 122C | 99C | 87C | 73C | 112C |
| Preconditioning Capacity | | 3.12 | 3.79 | 3.70 | 4.38 | 4.14 | 4.26 | 4.32 |
| 88 Days | Disch #1 | 1.84 | 2.48 | 3.30 | 4.00 | 3.65 | 3.33 | 1.05 |
| | Disch #2 | 2.39 | 3.50 | 3.33 | 4.23 | 3.62 | 3.50 | 1.20 |
| 176 Days | Disch #1 | 1.75 | 2.22 | 3.12 | 3.88 | 3.12 | 1.49 | 1.17 |
| | Disch #2 | 2.33 | 3.35 | 3.21 | 4.20 | 3.27 | 2.22 | 1.20 |
| 264 Days | Disch #1 | 1.55 | 2.45 | 2.89 | 3.06 | 2.80 | 1.46 | 1.20 |
| | Disch #2 | 2.25 | 2.80 | 3.00 | 4.03 | 2.95 | 2.33 | 1.23 |
| 352 Days | Disch #1 | 1.69 | 2.10 | 2.80 | 3.47 | 2.45 | 1.46 | 1.02 |
| | Disch #2 | 2.33 | 3.03 | 2.86 | 3.94 | 2.48 | 1.84 | 1.08 |

KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE

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POS. NO. CYCLE FAILED

PACK NUMBER 089C
TYPE OF CELLS GULTON 3.50 AH
TEST TEMPERATURE -20 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 0.96 AMP.

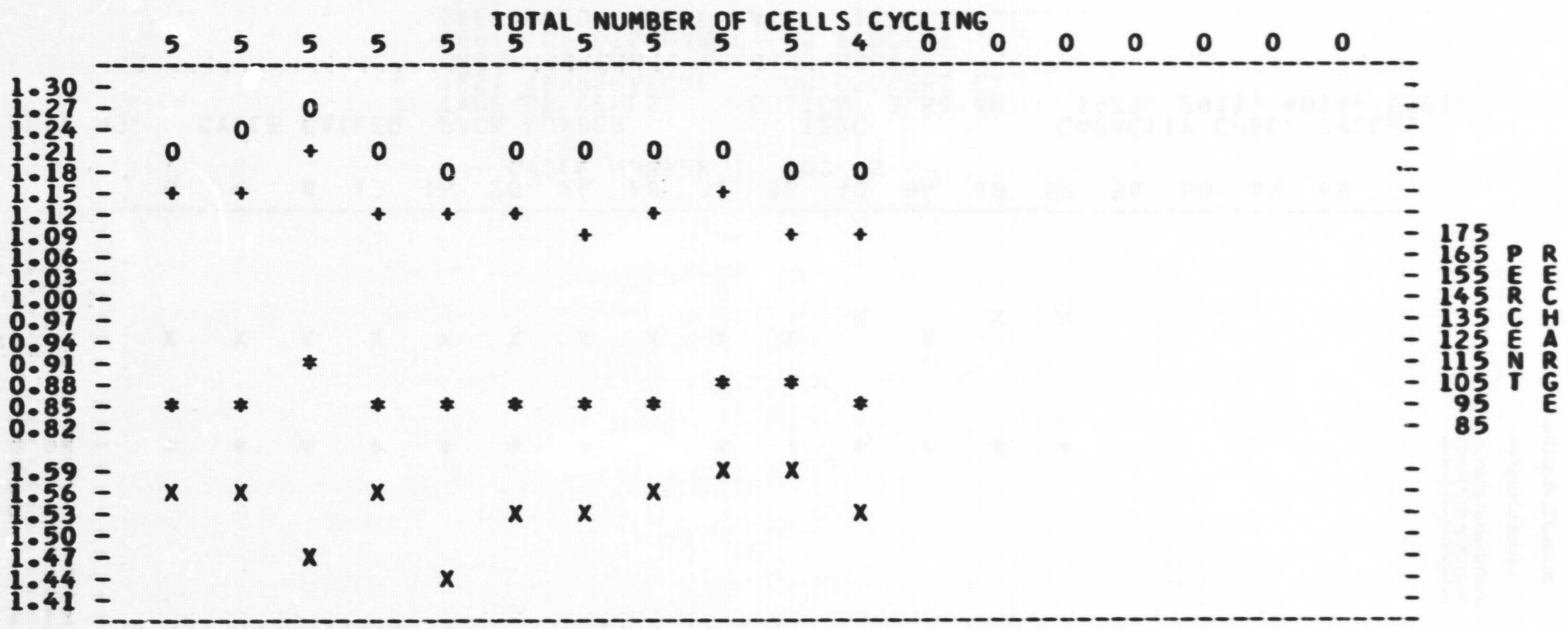
STATUS CELLS CYCLING 5
CYCLES COMPLETED 5507

CAPACITY CHECK CYCLES
1420, 2907, 4088, 5419,

FIGURE 16(A)

KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE

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POS. NO. 02

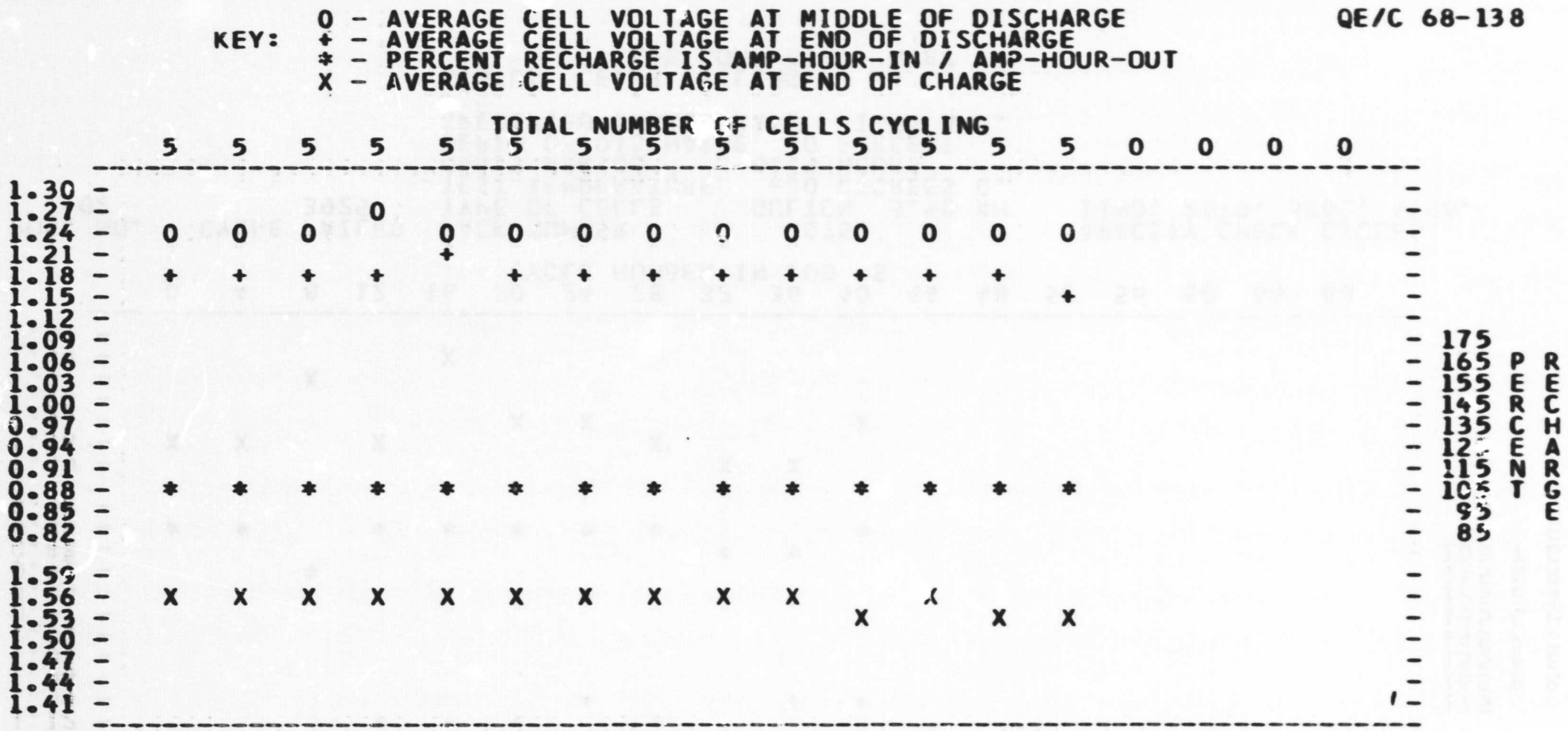
CYCLE FAILED 3925

PACK NUMBER 075D
TYPE OF CELLS GULTON 3.50 AH
TEST TEMPERATURE -20 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 40 PERCENT
SPECIFIED CHARGE RATE 1.54 AMP.

CAPACITY CHECK CYCLES
1190, 2679, 3860, 4196,

STATUS CELLS CYCLING 4
CYCLES COMPLETED 4287

FIGURE 16(B)



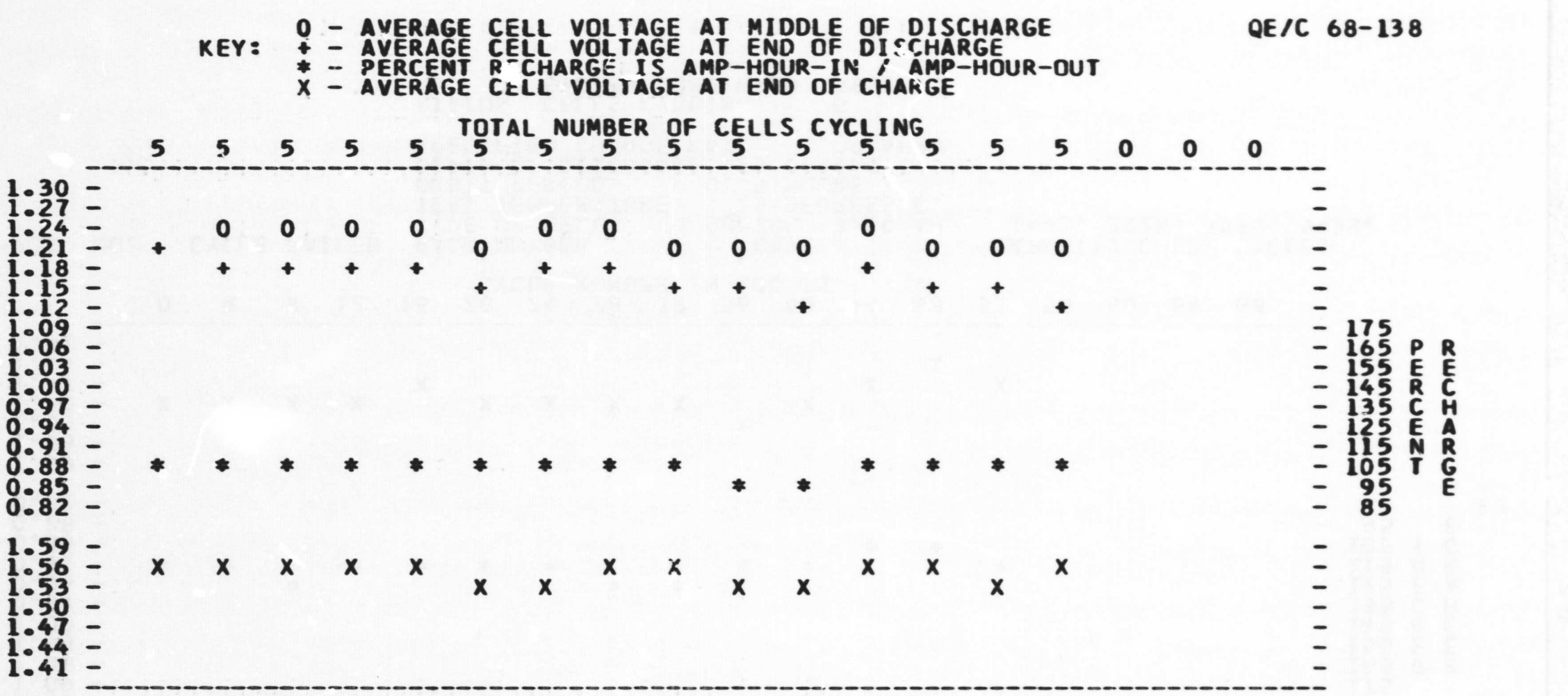

POS. NO. CYCLE FAILED

PACK NUMBER 122C
TYPE OF CELLS GULTON 3.50 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 1.01 AMP.

CAPACITY CHECK CYCLES
1427, 2911, 4014, 5421,

STATUS CELLS CYCLING 5
CYCLES COMPLETED 5543

FIGURE 16(C)



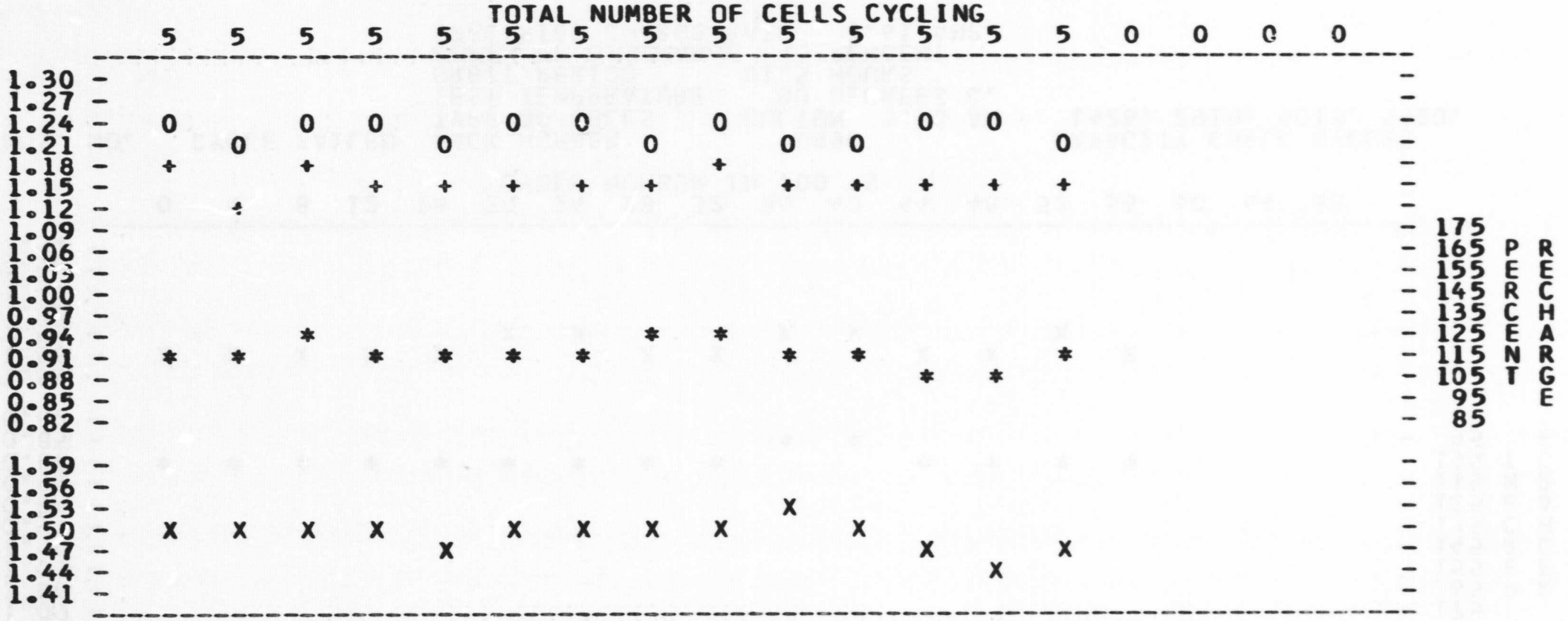

POS. NO. CYCLE FAILED

| | | |
|---|---|---|
| PACK NUMBER | 099C | CAPACITY CHECK CYCLES |
| TYPE OF CELLS | GULTON 3.50 AH | 1426, 2910, 4013, 5420, |
| TEST TEMPERATURE | 00 DEGREES C. | |
| ORBIT PERIOD | 01.5 HOURS | |
| DEPTH OF DISCHARGE | 40 PERCENT | |
| SPECIFIED CHARGE RATE | 1.61 AMP. | |
| STATUS | CELLS CYCLING 5 | |
| | CYCLES COMPLETED 5542 | |

FIGURE 16(D)

KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE

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POS. NO. CYCLE FAILED

PACK NUMBER 087C
TYPE OF CELLS GULTON 3.50 AH
TEST TEMPERATURE 25 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 1.09 AMP.

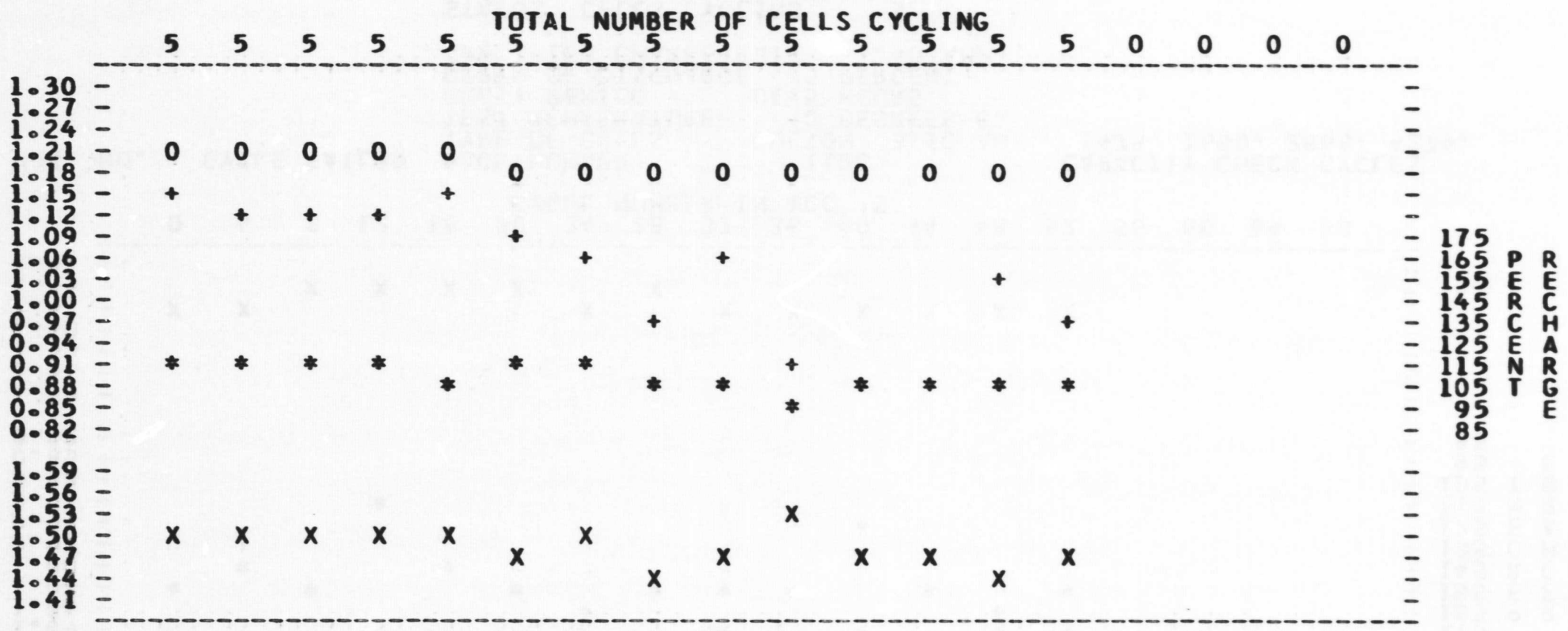
CAPACITY CHECK CYCLES
1442, 2928, 3999, 5438,

STATUS CELLS CYCLING 5
CYCLES COMPLETED 5560

FIGURE 16(E)

KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE

QE/C 68-138



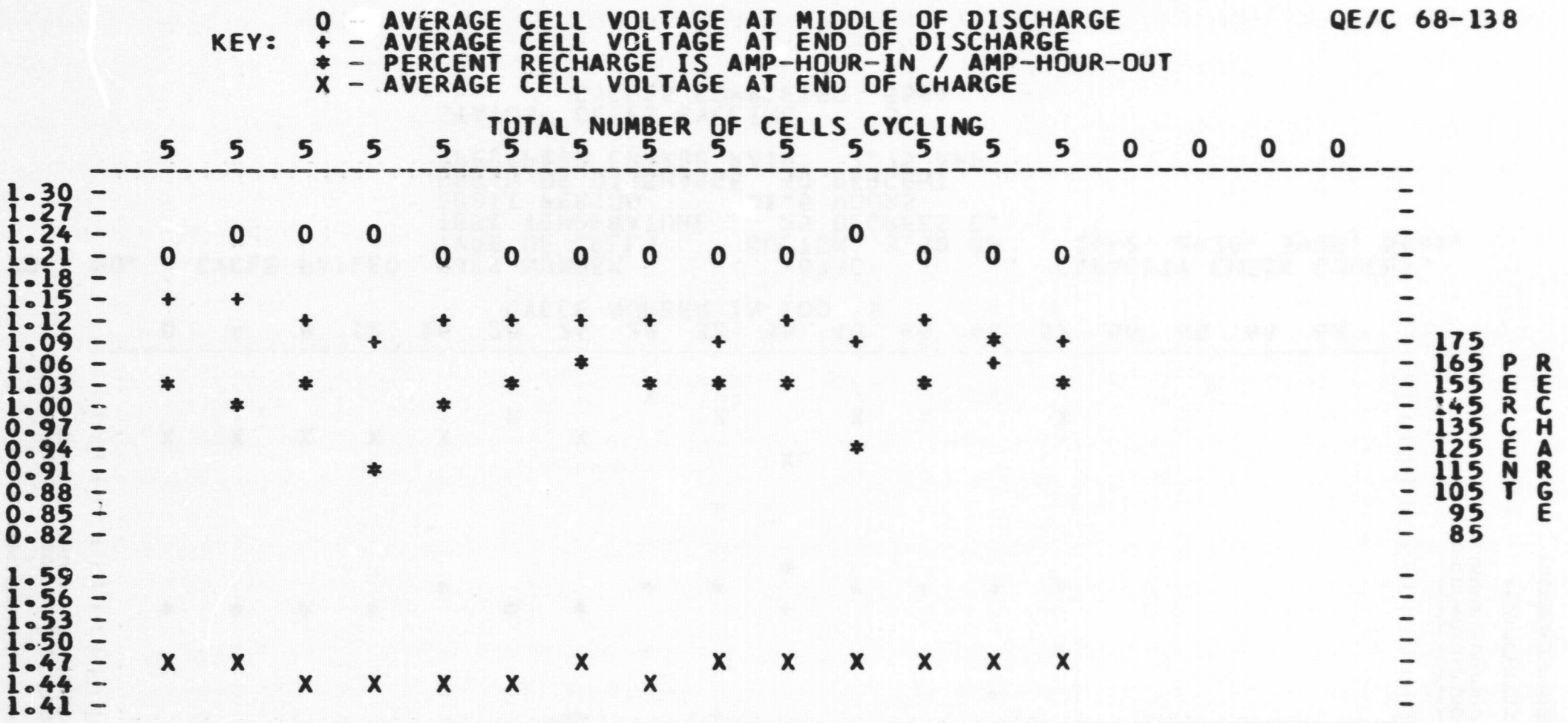

POS. NO. CYCLE FAILED

PACK NUMBER 073C
TYPE OF CELLS GULTON 3.50 AH
TEST TEMPERATURE 25 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 40 PERCENT
SPECIFIED CHARGE RATE 1.75 AMP.

CAPACITY CHECK CYCLES
1442, 2928, 3999, 5441,

STATUS CELLS CYCLING 5
CYCLES COMPLETED 5561

FIGURE 16(F)




POS. NO. CYCLE FAILED

PACK NUMBER 112C
TYPE OF CELLS GULTON 3.50 AH
TEST TEMPERATURE 40 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 1.40 AMP.

CAPACITY CHECK CYCLES
1473, 1650, 2866, 4274,

STATUS CELLS CYCLING 5
CYCLES COMPLETED 5402

FIGURE 16(G)

2. Gulton 4.0 ah (Commercial), Six 5-cell Packs, 1.5-hour Orbit Period:

a. Cell Description: These are rectangular sealed cells of commercial grade, but were not hermetically sealed as supplied. They were epoxy potted into 5-cell packs at the Goddard Space Flight Center in order to hermetically seal the cells before test.

b. Test Parameters:

| Pack Number | Test Temperature | Percent Depth of Discharge | Percent of Recharge | Charge Voltage Limit, Per Cell |
|---|---|---|---|---|
| 115B | 0° C | 15 | 115 | 1.55 ± 0.03 |
| 126B | 0° C | 25 | 115 | 1.55 ± 0.03 |
| 4B | 25° C | 25 | 125 | 1.49 ± 0.03 |
| 14B | 25° C | 40 | 125 | 1.49 ± 0.03 |
| 28B | 40° C | 15 | 160 | 1.45 ± 0.03 |
| 40B | 40° C | 25 | 160 | 1.45 ± 0.03 |

c. Test Results:

(1) Performance on cycling: (Figures 17(A) through 17(D).) Cycling was started in August 1964. These packs have completed from 8474 to 19,128 cycles with eight cell failures. Some leakage occurred as follows:

(a) Pack 115B: Leakage occurred under the epoxy, some of which resulted in carbonate deposits around the terminals embedded in the epoxy block.

(b) Pack 26B: Possible leakage under the epoxy.

(c) Pack 4B: Some leakage under the epoxy.

(d) Pack 14B: Leakage under the epoxy. A crack developed at the bottom of the epoxy case after 1785 cycles allowing escape of some electrolyte. Of the three cell failures in this pack, one developed a short, the other two appeared to have dried out. Welds between the terminals and the positive plate tabs were weak. Heavy separator deterioration was present in all three cells.

(e) Pack 28B: Some leakage under the epoxy. Cell position number 1 failed on cycle 17,021 and is awaiting the failure of the pack before it can be analyzed.

(f) Pack 40B: Leakage under the epoxy. All four failed cells had weak welds between the terminals and the positive plate tabs. One cell developed a short during cycling.

(2) Capacity checks: The ampere-hour capacities on the preconditioning and capacity check cycles are as follows:

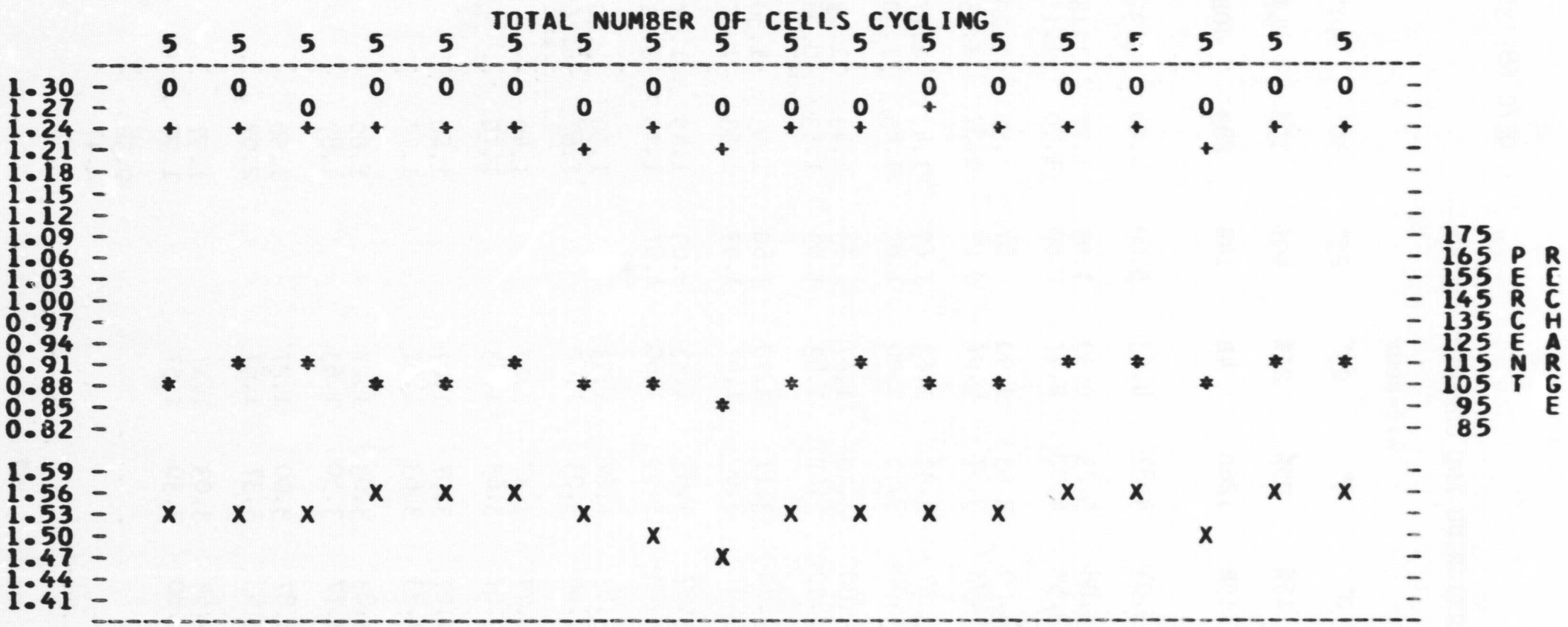
## PRECONDITIONING AND CAPACITY CHECKS

| Orbit Period | | 1.5-hour | | | | | |
|---|---|---|---|---|---|---|---|
| Temperature | | 0° | 0° | 25° | 25° | 40° | 40° |
| Depth of Discharge | | 15% | 25% | 25% | 40% | 15% | 25% |
| Pack Number | | 115B | 126B | 4B | 14B | 28B | 40B |
| Preconditioning Capacity | | 5.04 | 4.87 | 4.63 | 5.00 | 4.20 | 3.37 |
| 88 Days | Disch #1 | 3.28 | 3.23 | 2.30 | 1.93 | 1.77 | 1.13 |
| | Disch #2 | 3.57 | 4.00 | 2.47 | 2.00 | 1.70 | 1.17 |
| 176 Days | Disch #1 | 3.60 | 3.43 | 1.90 | 1.87 | 1.50 | 1.10 |
| | Disch #2 | 4.03 | 3.87 | 2.07 | 2.07 | 1.67 | 1.13 |
| 264 Days | Disch #1 | 3.67 | 3.33 | 1.63 | 1.67 | 1.47 | 1.17 |
| | Disch #2 | 4.00 | 3.73 | 1.80 | 1.87 | 1.43 | 1.30 |
| 352 Days | Disch #1 | 3.80 | 3.30 | 1.67 | 1.63 | 1.43 | 1.03 |
| | Disch #2 | 3.50 | 3.67 | 1.83 | 1.93 | 1.53 | 0.96 |
| 440 Days | Disch #1 | 3.80 | 3.17 | 1.70 | 1.80 | 1.93 | 1.30 |
| | Disch #2 | 4.07 | 3.60 | 1.67 | 1.93 | 1.53 | 1.17 |
| 528 Days | Disch #1 | 3.87 | 3.63 | 1.33 | 2.03 | 1.45 | 1.07 |
| | Disch #2 | 4.03 | 3.93 | 1.60 | 1.67 * | 1.75 | 0.93 |
| 616 Days | Disch #1 | 3.87 | 1.67 | 1.33 | | 1.50 | 1.00 |
| | Disch #2 | 4.60 | 3.03 | 1.60 | | 1.67 | 0.76 * |
| 704 Days | Disch #1 | 3.77 | 3.37 | 1.27 | | 1.40 | |
| | Disch #2 | 4.07 | 3.63 | 1.63 | | 1.70 | |
| 792 Days | Disch #1 | 4.27 | 3.07 | 1.27 | | 1.40 | |
| | Disch #2 | 4.33 | 3.63 | 1.67 | | 1.77 | |
| 888 Days | Disch #1 | 3.83 | 3.03 | 1.27 | | 1.60 | |
| | Disch #2 | 3.77 | 3.50 | 1.63 | | 1.87 | |
| 968 Days | Disch #1 | 3.87 | 3.00 | 1.27 | | 1.50 | |
| | Disch #2 | 4.03 | 3.37 | 1.67 | | 2.07 | |
| 1056 Days | Disch #1 | 3.53 | 3.03 | 1.17 | | 1.57 | |
| | Disch #2 | 3.80 | 3.30 | 1.57 | | 1.97 | |
| 1144 Days | Disch #1 | | | | | 0.32 | |
| | Disch #2 | | | | | 0.47 | |

*Pac Failed

KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE

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POS. NO. CYCLE FAILED

PACK NUMBER 115B
TYPE OF CELLS GULTON 4.00 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 15 PERCENT
SPECIFIED CHARGE RATE 0.69 AMP.

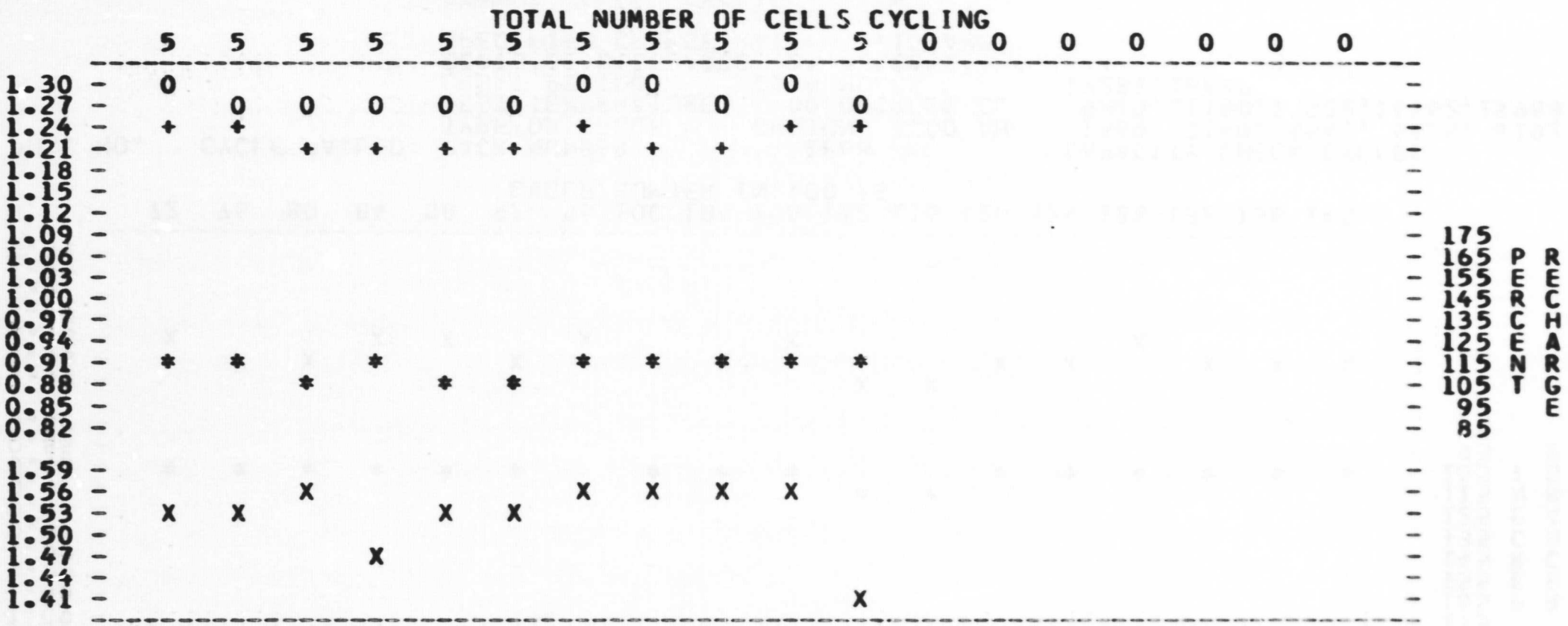
STATUS CELLS CYCLING 5
CYCLES COMPLETED 18695

CAPACITY CHECK CYCLES
1669, 3149, 4346, 5553, 6783
8310, 9900, 11692, 13680, 15278
16573, 17983,

FIGURE 17(A)

KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE

QE/C 68-138




POS. NO. CYCLE FAILED

PACK NUMBER 115B
TYPE OF CELLS GULTON 4.00 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 15 PERCENT
SPECIFIED CHARGE RATE 0.69 AMP.

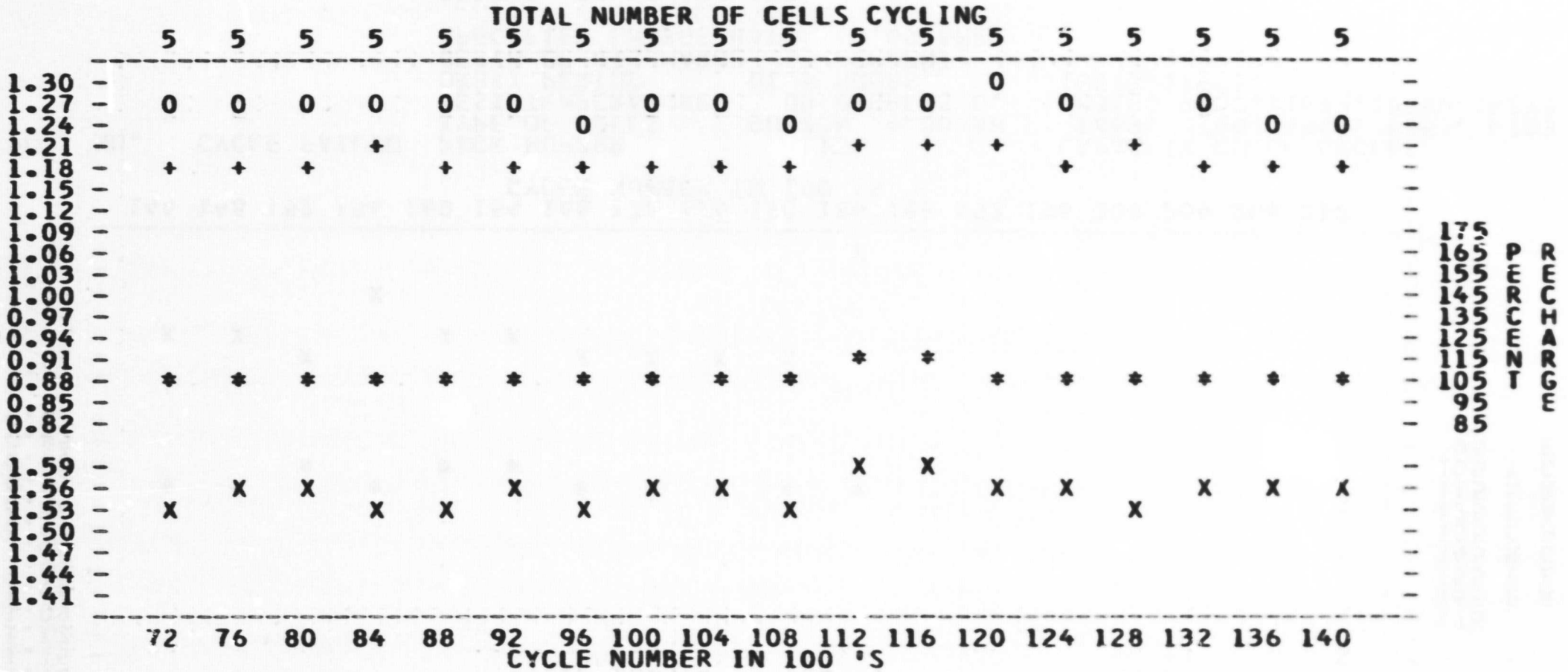
STATUS CELLS CYCLING 5
CYCLES COMPLETED 18695

CAPACITY CHECK CYCLES
1669, 3149, 4346, 5553, 6783
8310, 9900, 11692, 13680, 15278
16573, 17983,

FIGURE 17(A) (CONTD)

KEY: 0 – AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ – AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* – PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X – AVERAGE CELL VOLTAGE AT END OF CHARGE

QE/C 68-138




POS. NO. CYCLE FAILED

PACK NUMBER 126B
TYPE OF CELLS GULTON 4.00 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 1.15 AMP.

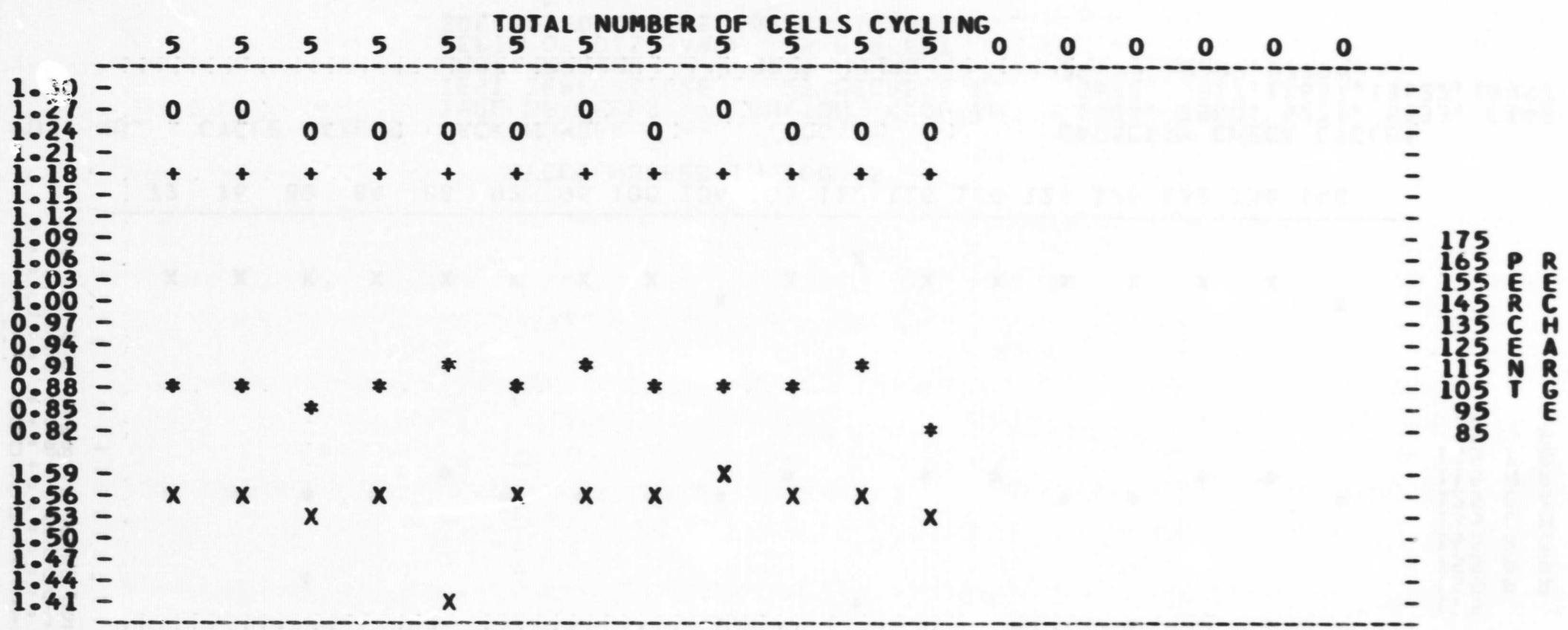
STATUS CELLS CYCLING 5
CYCLES COMPLETED 19128

CAPACITY CHECK CYCLES
1669, 3149, 4545, 6625, 8192
9819, 11180, 12908, 14562, 15968
17231, 18670,

FIGURE 17(B)

KEY: O – AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ – AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* – PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X – AVERAGE CELL VOLTAGE AT END OF CHARGE

QE/C 68-138




POS. NO. CYCLE FAILED

PACK NUMBER 126B
TYPE OF CELLS GULTON 4.00 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 1.15 AMP.

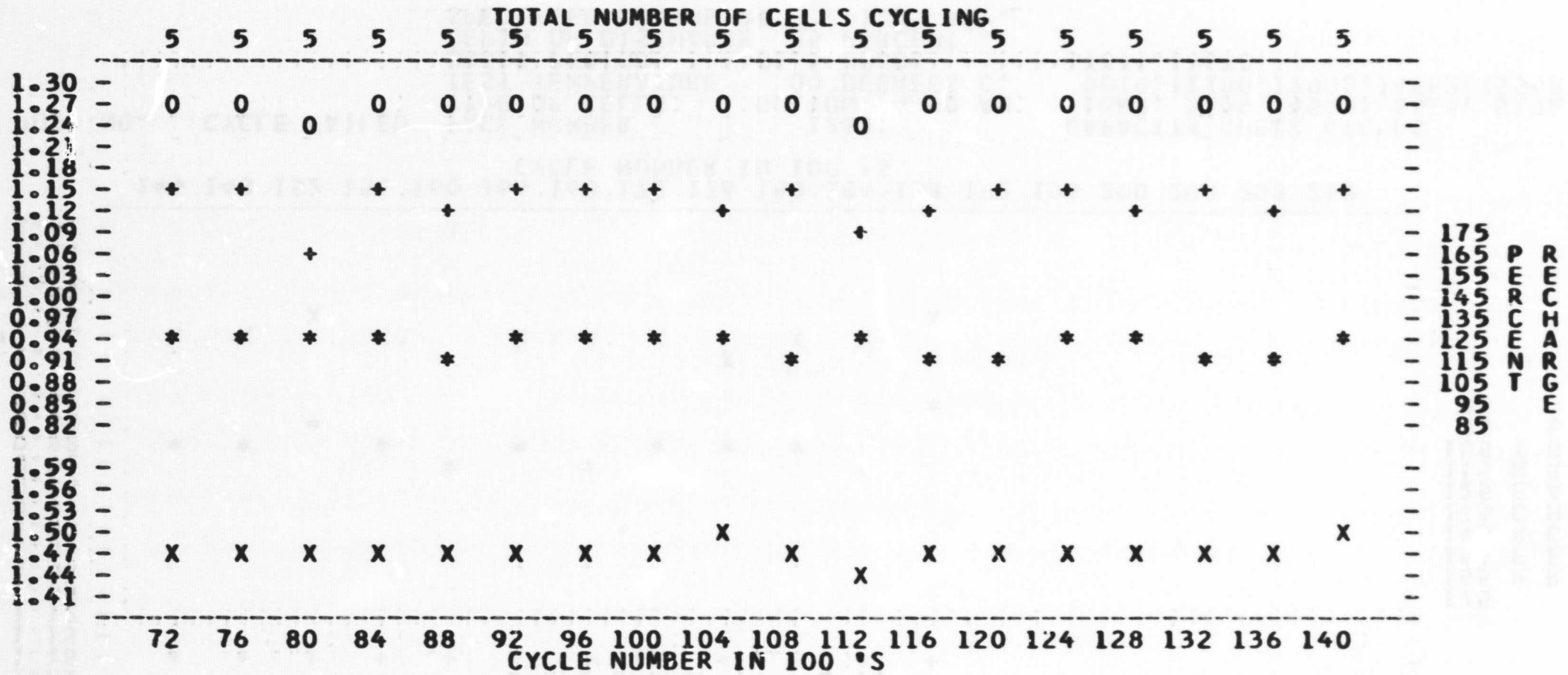
CAPACITY CHECK CYCLES
1669, 3149, 4545, 6625, 8192
9819,11180,12908,14562,15968
17231,18670,

STATUS CELLS CYCLING 5
CYCLES COMPLETED 19128

FIGURE 17(B) (CONTD)

KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE

QE/C 68-138




POS. NO. CYCLE FAILED

PACK NUMBER 004B
TYPE OF CELLS GULTON 4.00 AH
TEST TEMPERATURE 25 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 1.25 AMP.

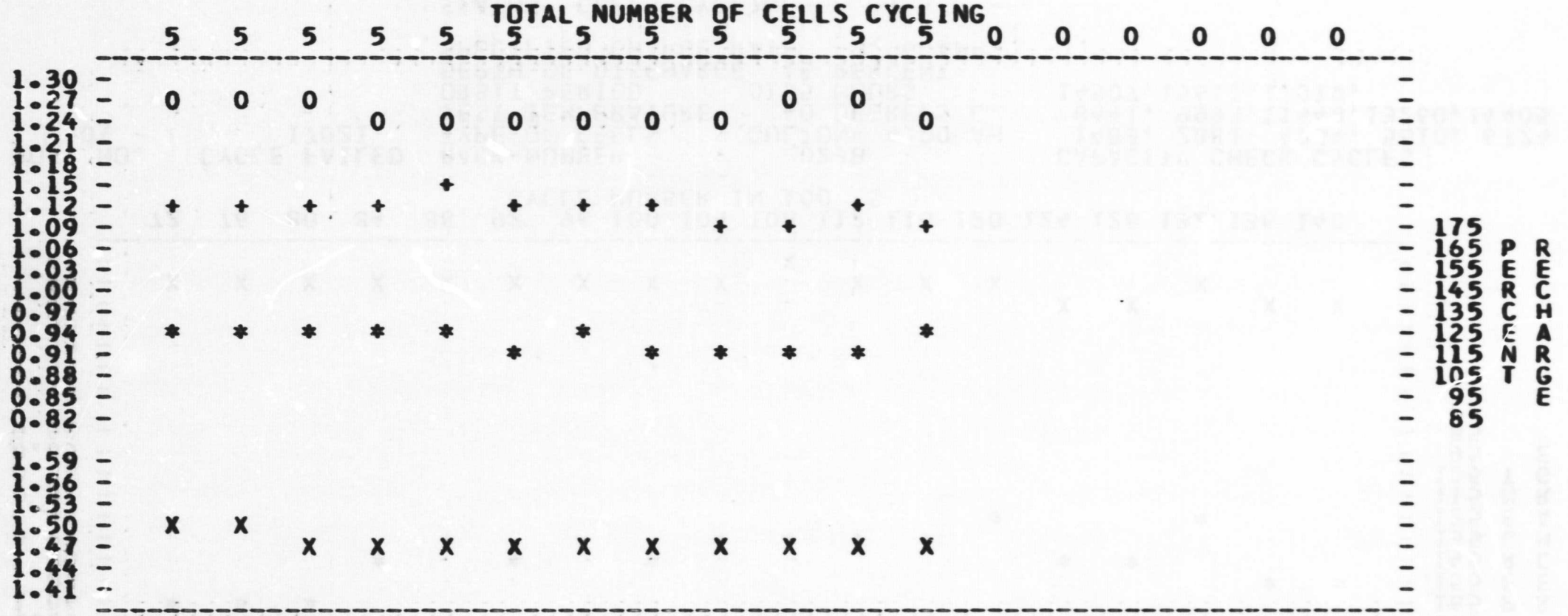
CAPACITY CHECK CYCLES
1484, 2880, 4271, 5933, 7142
8692,10317,11637,13622,14997
15174,16387,17794,

STATUS CELLS CYCLING 5
CYCLES COMPLETED 18924

FIGURE 17(C)

KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE

QE/C 68-138




POS. NO. CYCLE FAILED

PACK NUMBER 004B
TYPE OF CELLS GULTON 4.00 AH
TEST TEMPERATURE 25 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 1.25 AMP.

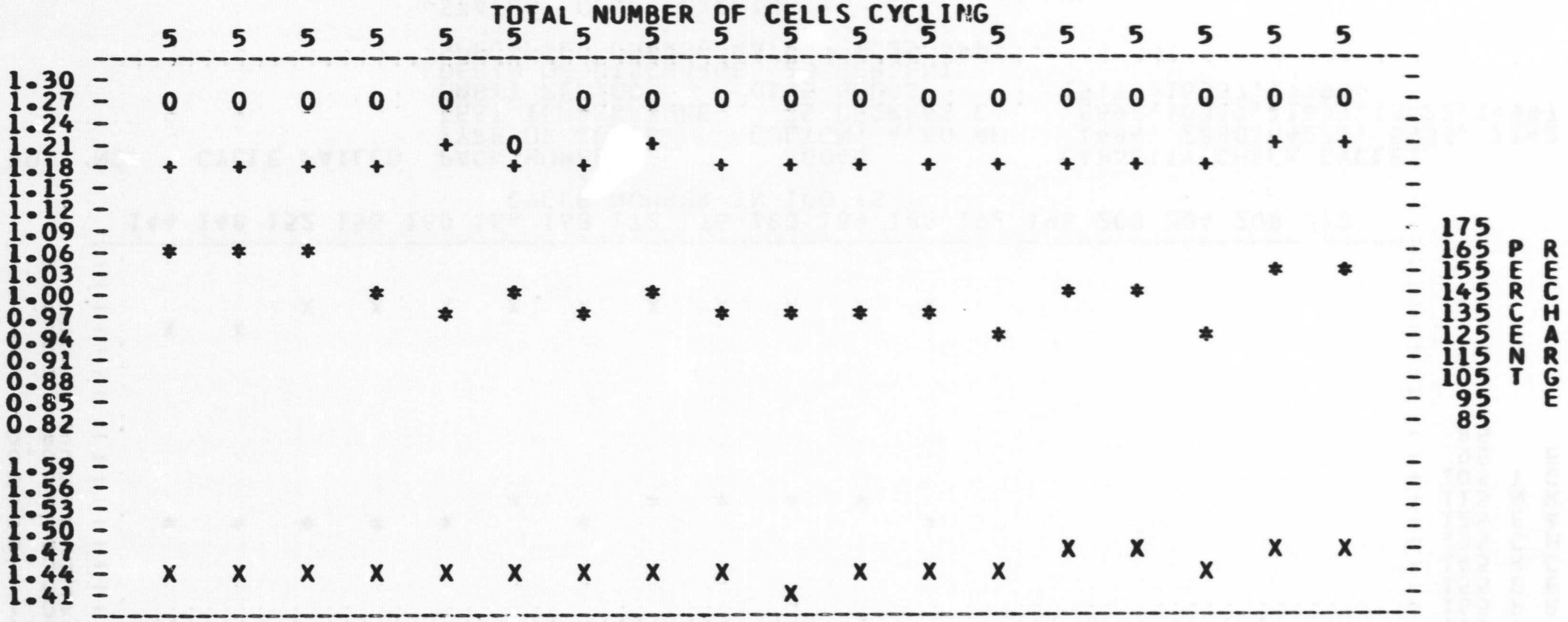
STATUS CELLS CYCLING 5
CYCLES COMPLETED 18924

CAPACITY CHECK CYCLES
1484, 2880, 4271, 5933, 7142
8692,10317,11637,13622,14997
15174,16387,17794,

FIGURE 17(C) (CONTD)

KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE

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POS. NO. 01

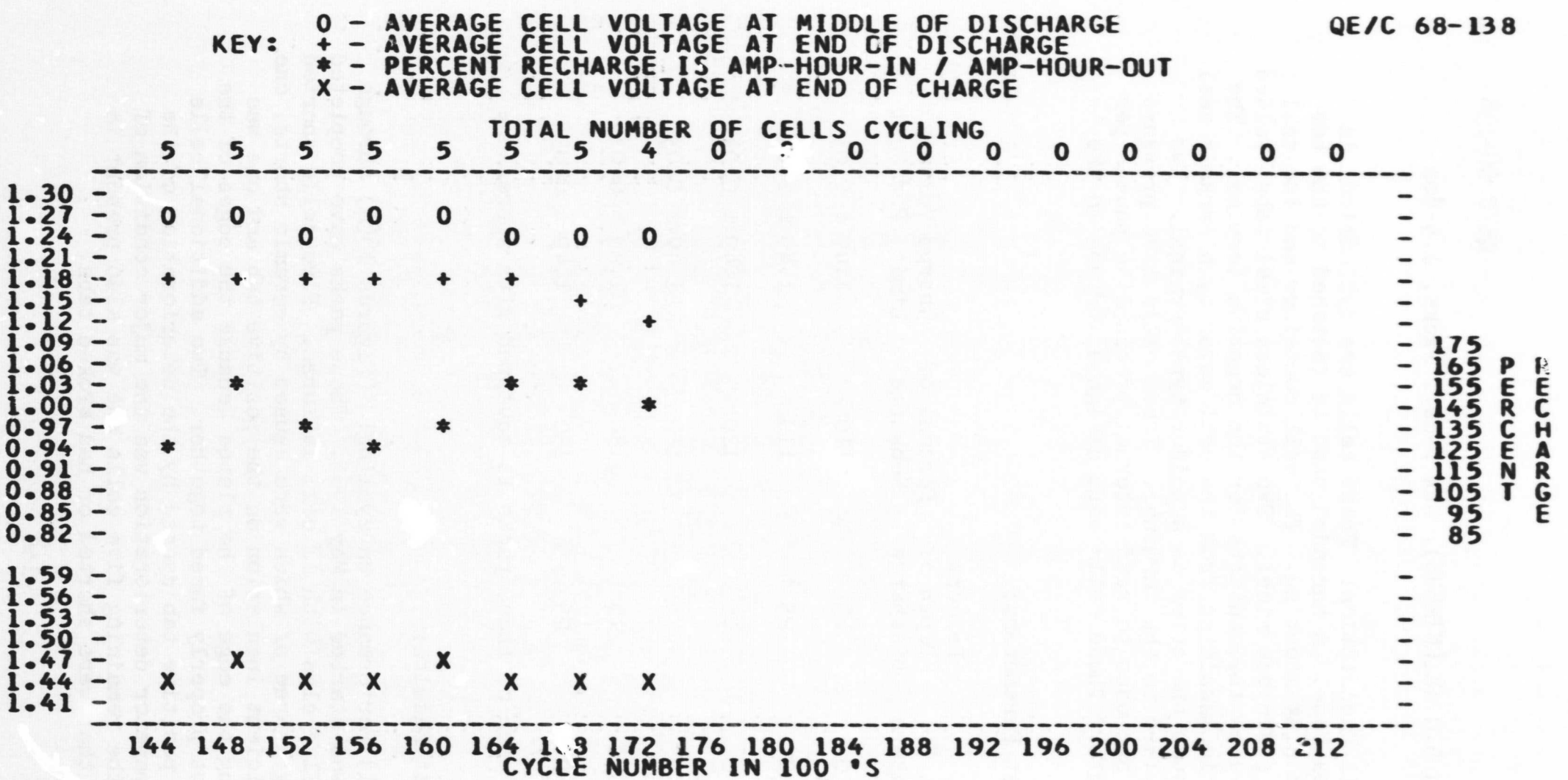
CYCLE FAILED 17021

PACK NUMBER 0288
TYPE OF CELLS GULTON 4.00 AH
TEST TEMPERATURE 40 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 15 PERCENT
SPECIFIED CHARGE RATE 0.96 AMP.

STATUS CELLS CYCLING 4
CYCLES COMPLETED 17187

CAPACITY CHECK CYCLES
1483, 2881, 4254, 5610, 6724
8441, 9993, 11448, 13260, 14405
14507, 15611, 17019,

FIGURE 17(D)




POS. NO. CYCLE FAILED
01 17021

PACK NUMBER 0288
TYPE OF CELLS GULTON 4.00 AH
TEST TEMPERATURE 40 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 15 PERCENT
SPECIFIED CHARGE RATE 0.96 AMP.

STATUS CELLS CYCLING 4
CYCLES COMPLETED 17187

CAPACITY CHECK CYCLES
1483, 2881, 4254, 5610, 6724
8441, 9993,11448,13260,14405
14507,15611,17019,

FIGURE 17(D) (CONTD)

3. Gulton 5.0 ah (NIMBUS), Six 5-cell Packs, 1.5-hour Orbit Period:

a. Cell Description: These cells are cylindrical in shape with a convex base. A threaded stud is fastened to the base to facilitate heat sink mounting. The cell container and the cell cover are made of stainless steel. Two stainless steel tabs, welded to the cover, serve as the contacts for the negative terminal. The positive terminal is insulated from the cell cover by a ceramic seal and protrudes through the cover as a solder type terminal. Two solder tabs are welded to the terminal. Three cells have pressure transducers which are used to read internal pressure in pounds per square inch absolute. These cells were designed for use in the NIMBUS satellite.

b. Test Parameters:

| Pack Number | Test Temperature | Percent Depth of Discharge | Percent of Recharge | Charge Voltage Limit, Per Cell |
|---|---|---|---|---|
| 117A | 0° C | 15 | 110 | 1.49 ± 0.03 |
| 121A* | 0° C | 25 | 110 | 1.49 ± 0.03 |
| 120A | 25° C | 15 | 120 | 1.49 ± 0.03 |
| 118B* | 25° C | 25 | 120 | 1.49 ± 0.03 |
| 127A | 40° C | 15 | 130 | 1.49 ± 0.03 |
| 128A* | 40° C | 25 | 130 | 1.49 ± 0.03 |

* One cell in each of these packs is equipped with a pressure transducer.

c. Test Results:

(1) Performance on cycling: (Figures 18(A) through 18(D).) Cycling was started in May 1965. These packs have completed from 6345 to 14,871 cycles with 12 cell failures. Five cells shorted out during cycling; three of which were caused by ceramic shorts, one was due to insufficient insulation on the positive tab and one was due to shorts along the edge of the plates because the edges of the separators were not properly fused together. Two additional cells had breaks in the positive tab caused by the deterioration of the tab material. Separator deterioration was the major condition of failure found in the remaining five cells and was also present in some of the cells that were shorted or had broken tabs.

(2) Capacity checks: The ampere-hour capacities on the preconditioning and capacity check cycles are as follows:

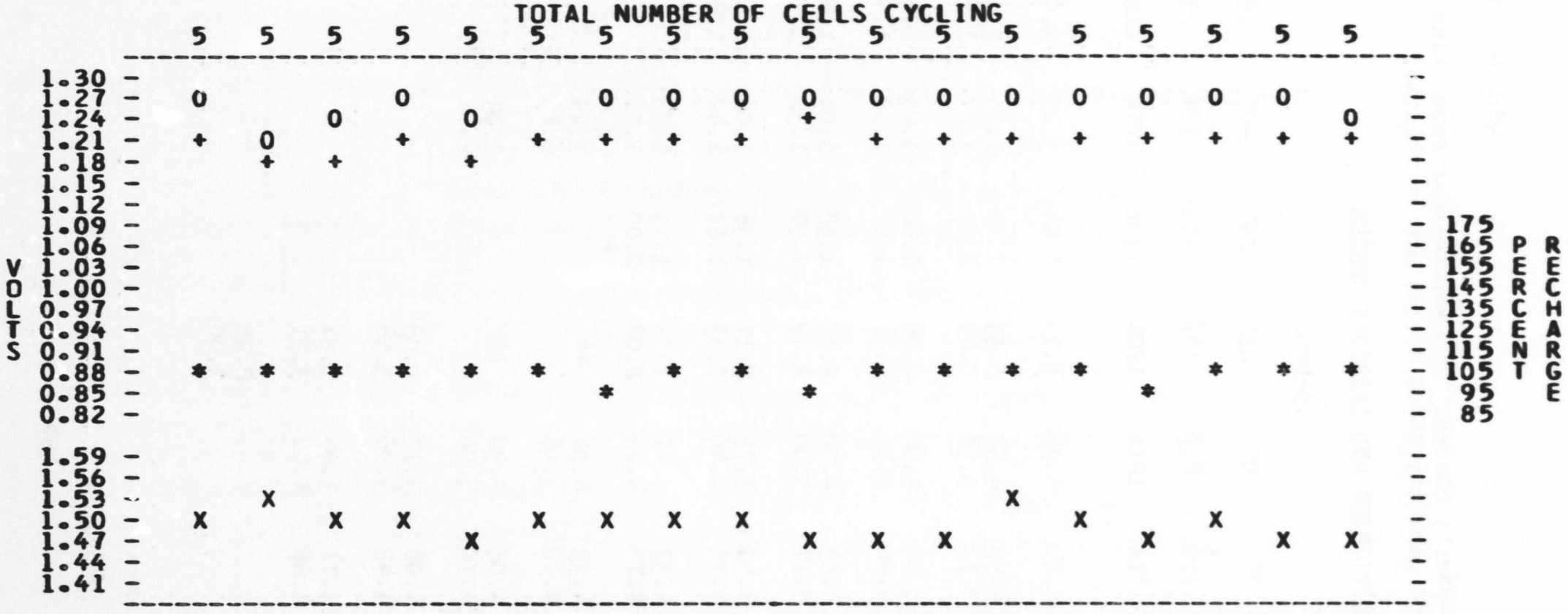
PRECONDITIONING AND CAPACITY CHECKS

| Orbit Period | | 1.5-hour | | | | | |
|---|---|---|---|---|---|---|---|
| Temperature | | 0° | 0° | 25° | 25° | 40° | 40° |
| Depth of Discharge | | 15% | 25% | 15% | 25% | 15% | 25% |
| Pack Number | | 117A | 121A | 120A | 118B | 127A | 128A |
| Preconditioning Capacity | | 5.00 | 5.38 | 5.25 | 5.46 | 3.29 | 3.04 |
| 88 Days | Disch #1 | 4.96 | 4.92 | 5.33 | 1.79 | 1.29 | 1.17 |
| | Disch #2 | 5.17 | 5.38 | 5.40 | 2.55 | 1.67 | 1.42 |
| 176 Days | Disch #1 | 5.00 | 4.88 | 2.96 | 1.42 | 1.25 | 1.38 |
| | Disch #2 | 5.46 | 5.33 | 4.17 | 1.67 | 1.50 | 1.54 |
| 264 Days | Disch #1 | 4.63 | 4.00 | 2.75 | 1.38 | 1.04 | 1.46 |
| | Disch #2 | 5.17 | 5.00 | 2.79 | 1.50 | 1.38 | 1.71 |
| 352 Days | Disch #1 | 4.50 | 3.75 | 2.17 | 1.38 | 1.08 | 1.67 |
| | Disch #2 | 4.75 | 4.46 | 2.33 | 1.67 | 1.42 | 1.83 * |
| 440 Days | Disch #1 | 4.33 | 3.42 | 1.75 | 1.13 | 1.25 | |
| | Disch #2 | 4.75 | 4.29 | 2.08 | 2.00 * | 1.71 | |
| 528 Days | Disch #1 | 4.33 | 4.04 | ** | | 1.46 | |
| | Disch #2 | 4.50 | 3.96 | | | 2.25 | |
| 616 Days | Disch #1 | 4.08 | 2.38 | ** | | 1.13 | |
| | Disch #2 | 4.70 | 3.96 | | | 2.04 | |
| 704 Days | Disch #1 | 4.08 | 3.17 | 3.08 | | | |
| | Disch #2 | 4.42 | 3.96 | 3.58 | | | |
| 792 Days | Disch #1 | 3.71 | 3.04 | 2.54 | | | |
| | Disch #2 | 4.08 | 4.08 | 3.21 | | | |
| 888 Days | Disch #1 | | | 2.25 | | | |
| | Disch #2 | | | 3.00 | | | |

* Pack Failed
** Missed Capacity Check

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KEY: 0 – AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ – AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* – PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X – AVERAGE CELL VOLTAGE AT END OF CHARGE




POS. NO. CYCLE FAILED

PACK NUMBER 117A
TYPE OF CELLS GULTON 5.00 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 15 PERCENT
SPECIFIED CHARGE RATE 0.83 AMP.

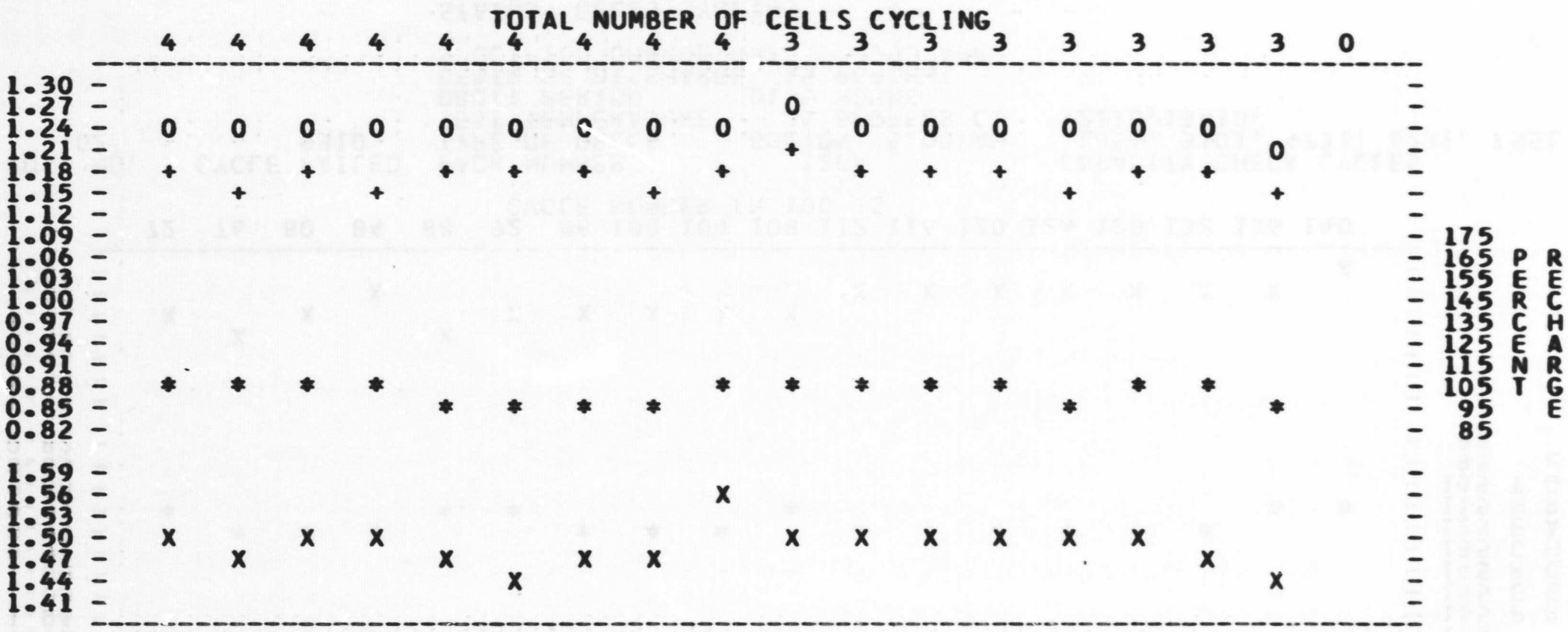
STATUS CELLS CYCLING 5
CYCLES COMPLETED 14430

CAPACITY CHECK CYCLES
1721, 2967, 4517, 6100, 7369
9270,10539,10790,11973,13412
0,

FIGURE 18(A)

KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE

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| POS. NO. | CYCLE FAILED | | |
|---|---|---|---|
| 01 | 6694 | PACK NUMBER | 121A |
| 04 | 10803 | TYPE OF CELLS | GULTON 5.00 AH |
| | | TEST TEMPERATURE | 00 DEGREES C. |
| | | ORBIT PERIOD | 01.5 HOURS |
| | | DEPTH OF DISCHARGE | 25 PERCENT |
| | | SPECIFIED CHARGE RATE | 1.38 AMP. |

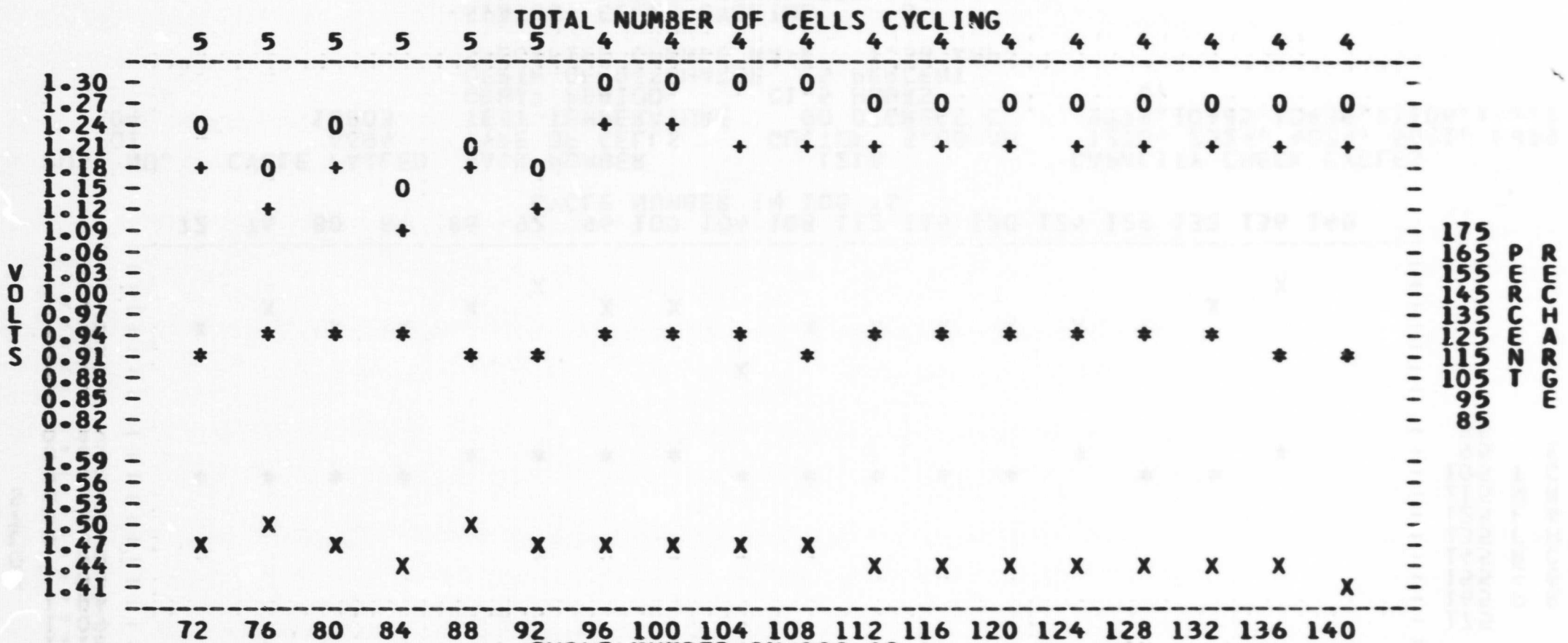
CAPACITY CHECK CYCLES
1278, 2524, 4074, 5611, 6819
8778,10185,10436,11606,13112
0,

STATUS CELLS CYCLING 3
CYCLES COMPLETED 14016

FIGURE 18(B)

KEY: 0 – AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ – AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* – PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X – AVERAGE CELL VOLTAGE AT END OF CHARGE

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POS. NO. 02 CYCLE FAILED 9310

PACK NUMBER 120A
TYPE OF CELLS GULTON 5.00 AH
TEST TEMPERATURE 25 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 15 PERCENT
SPECIFIED CHARGE RATE 0.90 AMP.

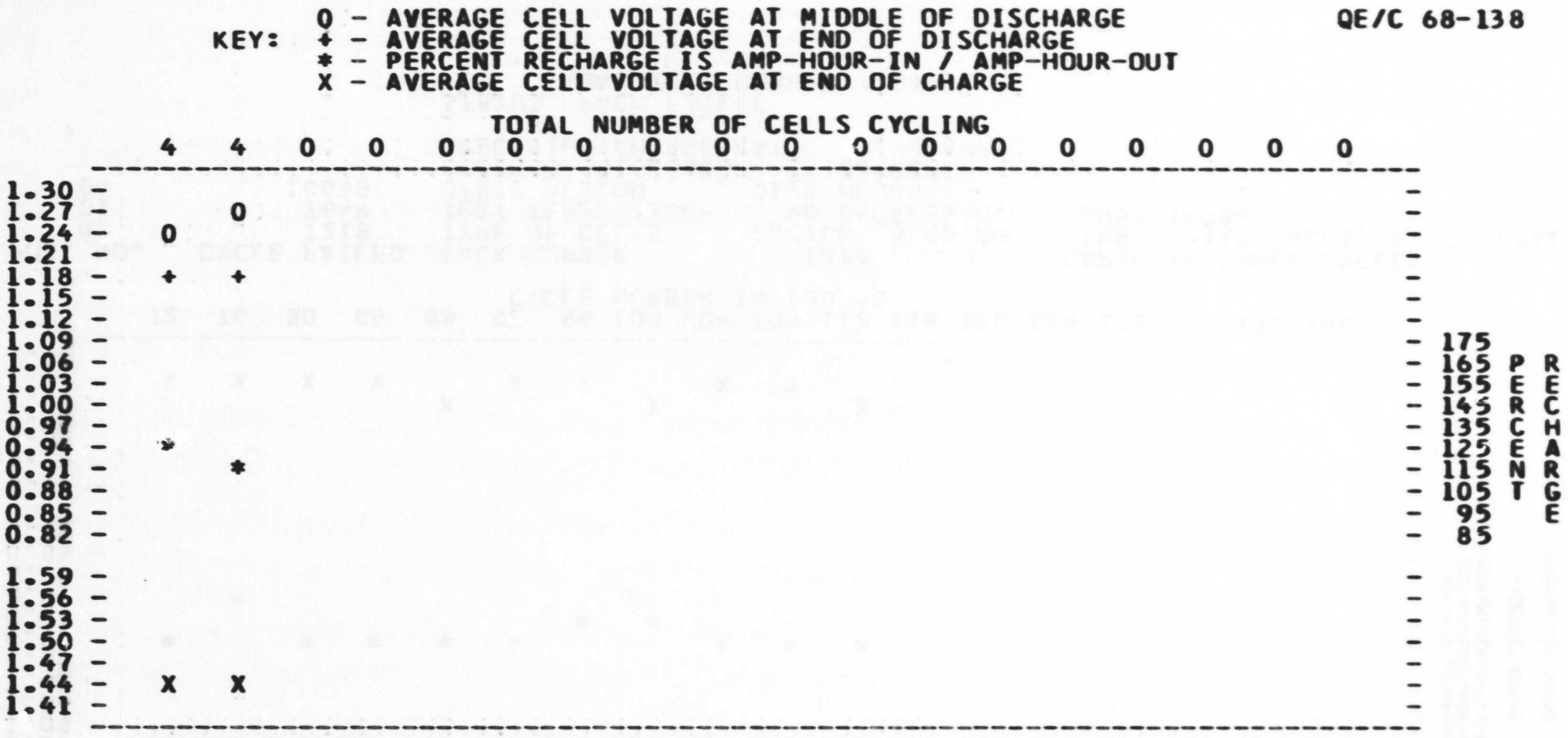
STATUS CELLS CYCLING 4
CYCLES COMPLETED 14871

CAPACITY CHECK CYCLES
1854, 3101, 4731, 6231, 7551
12220, 13410,

FIGURE 18(C)

KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE

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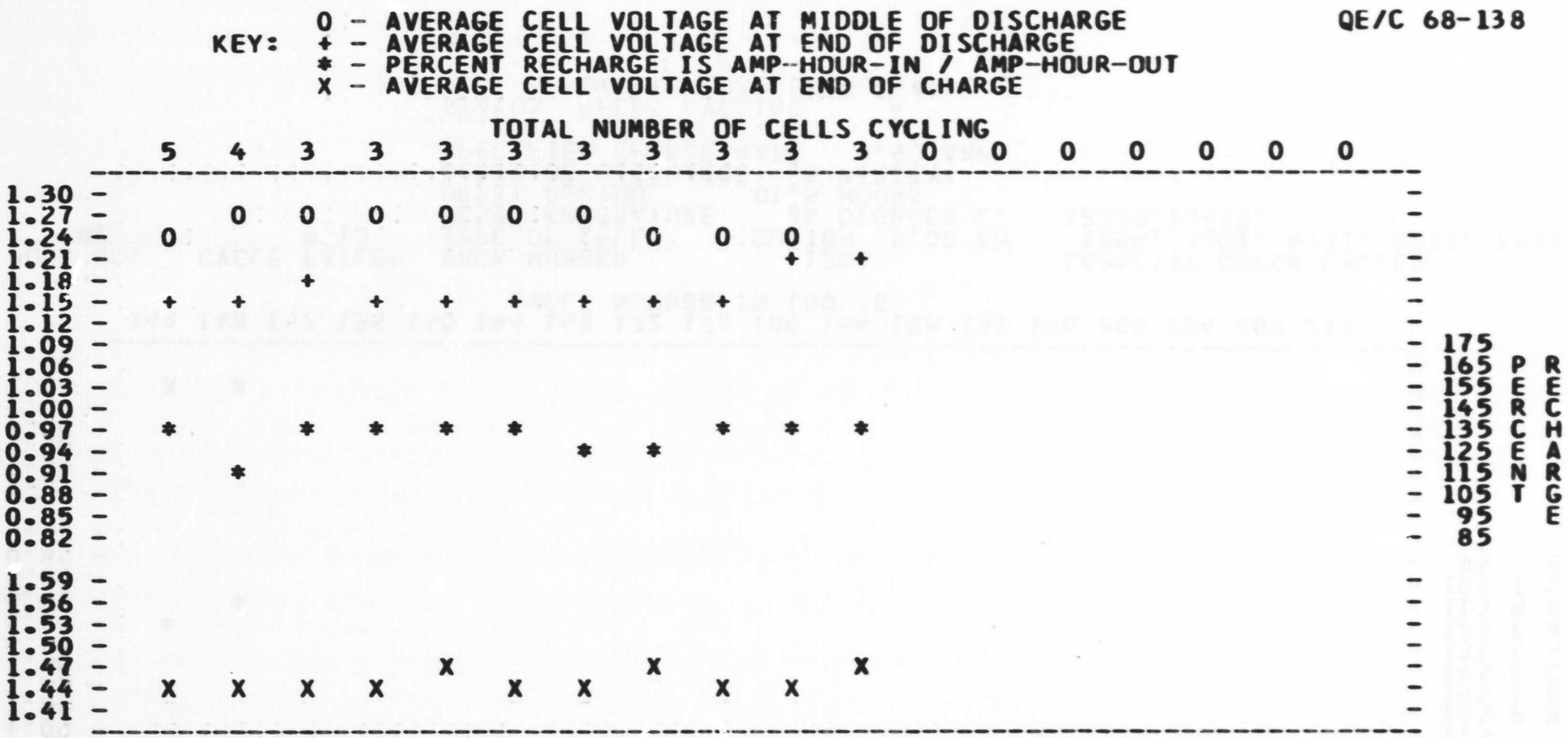

POS. NO. 02 — CYCLE FAILED 9310

PACK NUMBER 120A
TYPE OF CELLS GULTON 5.00 AH
TEST TEMPERATURE 25 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 15 PERCENT
SPECIFIED CHARGE RATE 0.90 AMPS.

CAPACITY CHECK CYCLES
1854, 3101, 4731, 6231, 7551
12220,13410,

STATUS CELLS CYCLING 4
CYCLES COMPLETED 14871

FIGURE 18(C) (CONTD)




| POS. NO. | CYCLE FAILED |
|---|---|
| 02 | 7218 |
| 01 | 7649 |
| 04 | 10638 |

PACK NUMBER 127A
TYPE OF CELLS GULTON 5.00 AH
TEST TEMPERATURE 40 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 15 PERCENT
SPECIFIED CHARGE RATE 0.98 AMP.

CAPACITY CHECK CYCLES
1897, 3115, 4666, 6247, 7331
8950,10036,

STATUS PACK FAILED
ON CYCLE NUMBER 10638

FIGURE 18(D)

4. Gulton 5.6 ah (Neoprene Seal), Eight 5-cell Packs, 1.5-hour Orbit Period:

a. Cell Description: These cells are cylindrical in shape. The cell containers and the cell covers are made of cold rolled steel. The positive terminal is insulated from the cell cover by a vulcanized neoprene bushing and protrudes through the bushing as a 1/8 inch projection. The vulcanized neoprene bushings used in the folded cover to terminal seals are longer than those used in the nonfolded cover to terminal seals to protrude through the sleeve formed by the inward fold at the center of the cover (see Figure 19). This design results in a greater length of seal and affords greater protection to the seal from heat during welding of the cover to the can. The possible damage to the neoprene seal of either type cover to terminal seal, by attempting to solder electrical connections to the 1/8 inch positive terminals made it necessary to spot weld metal tabs to these terminals. Metal tabs were also spot welded to the bottom of the cans to serve as the negative terminals.

b. Test Parameters:

| Pack Number | Test Temperature | Percent Depth of Discharge | Percent of Recharge | Charge Voltage Limit, Per Cell | Seal |
|---|---|---|---|---|---|
| 44B | -20° C | 25 | 115 | 1.55 ± 0.03 | Folded |
| 32B | -20° C | 25 | 115 | 1.55 ± 0.03 | Nonfolded |
| 100B | 0° C | 25 | 115 | 1.55 ± 0.03 | Folded |
| 90C | 0° C | 25 | 115 | 1.55 ± 0.03 | Nonfolded |
| 76B | 25° C | 25 | 125 | 1.49 ± 0.03 | Folded |
| 96C | 25° C | 25 | 125 | 1.49 ± 0.03 | Nonfolded |
| 42B | 40° C | 25 | 160 | 1.45 ± 0.03 | Folded |
| 30B | 40° C | 25 | 160 | 1.45 ± 0.03 | Nonfolded |

c. Test Results:

(1) Performance on cycling: (Figures 20(A) through 20(F).) Cycling was started in December 1965. These packs have completed from 1275 to 11,238 cycles with 11 cell failures. The average end-of-discharge voltage was highest for cells cycling at 0° C; also there was less variation in the voltages at this temperature.

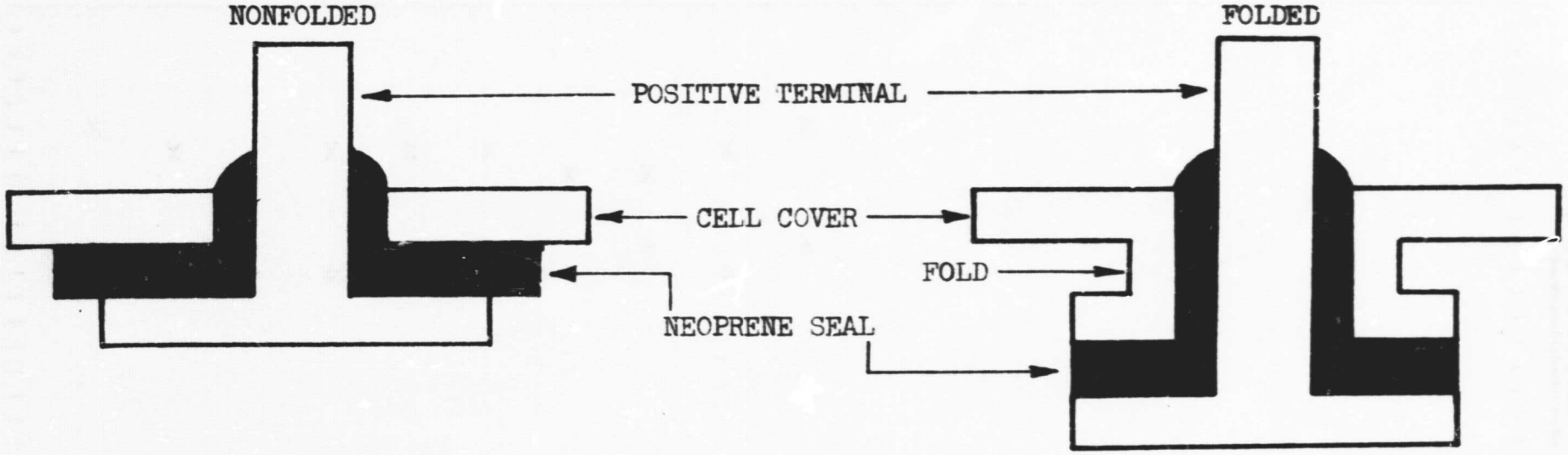
(a) All failed cells showed signs of leakage in the form of deposits around the seal, and around the welded cover to can seams of both the folded and nonfolded terminal seal types. Several cells had burned positive tabs. Separator deterioration was also present in all failures after 2743 cycles.

(2) Capacity checks: The ampere-hour capacities on the preconditioning and capacity check cycles are as follows:

PRECONDITIONING AND CAPACITY CHECKS

| Orbit Period | | 1.5-hour | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Temperature | | -20° | -20° | 0° | 0° | 25° | 25° | 40° | 40° |
| Depth of Discharge | | 25% | 25% | 25% | 25% | 25% | 25% | 25% | 25% |
| Pack Number | | 44B | 32B | 100B | 90C | 76B | 96C | 42B | 30B |
| Preconditioning Capacity | | 4.01 | 4.53 | 6.25 | 6.58 | 5.60 | 6.30 | 4.39 | 4.90 * |
| 88 Days | Disch #1 | 3.50 | 3.36 | 4.95 | 5.23 | 1.54 | 1.73 | 1.40 | |
| | Disch #2 | 4.67 | 4.57 | 5.32 | 5.88 | 1.63 | 2.33 | 1.49 | |
| 176 Days | Disch #1 | 3.03 | 3.27 | 4.95 | 4.66 | 1.45 | 2.05 | 1.35 | |
| | Disch #2 | 4.34 | 4.67 | 5.09 | 5.50 | 1.59 | 2.24 | 1.35 * | |
| 264 Days | Disch #1 | 2.10 | 2.10 | 4.39 | 4.71 | 1.35 | 1.49 | | |
| | Disch #2 | 3.36 | 3.64 | 4.85 | 5.27 | 1.59 | 1.87 | | |
| 352 Days | Disch #1 | 2.43 | 2.47 | 4.06 | 4.29 | 1.40 | 2.10 | | |
| | Disch #2 | 3.36 | 3.45 | 4.39 | 4.85 | 1.63 | 2.85 | | |
| 440 Days | Disch #1 | 3.22 | 2.39 | 3.87 | 3.69 | 1.91 | 1.73 | | |
| | Disch #2 | 3.64 | 3.64 | 4.25 | 4.48 | 2.10 | 2.33 | | |
| 528 Days | Disch #1 | | 2.10 | 3.45 | 3.13 | 1.31 | 1.49 | | |
| | Disch #2 | | 3.27 | 3.83 | 3.97 | 1.49 | 2.38 * | | |
| 616 Days | Disch #1 | | | 3.31 | 3.08 | 1.26 | | | |
| | Disch #2 | | | 3.64 | 3.64 | 1.17 | | | |

* Pack Failed

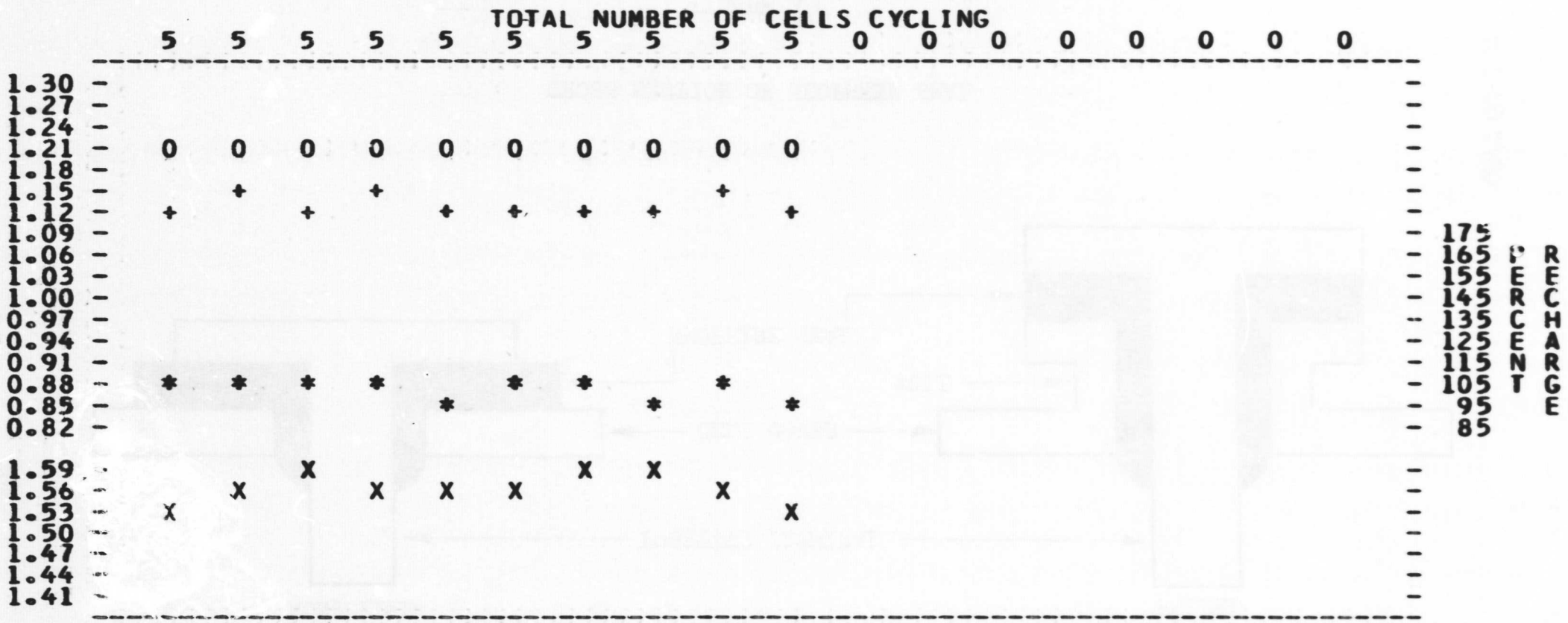



CROSS SECTION OF NEOPRENE SEAL

FIGURE 19

KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE

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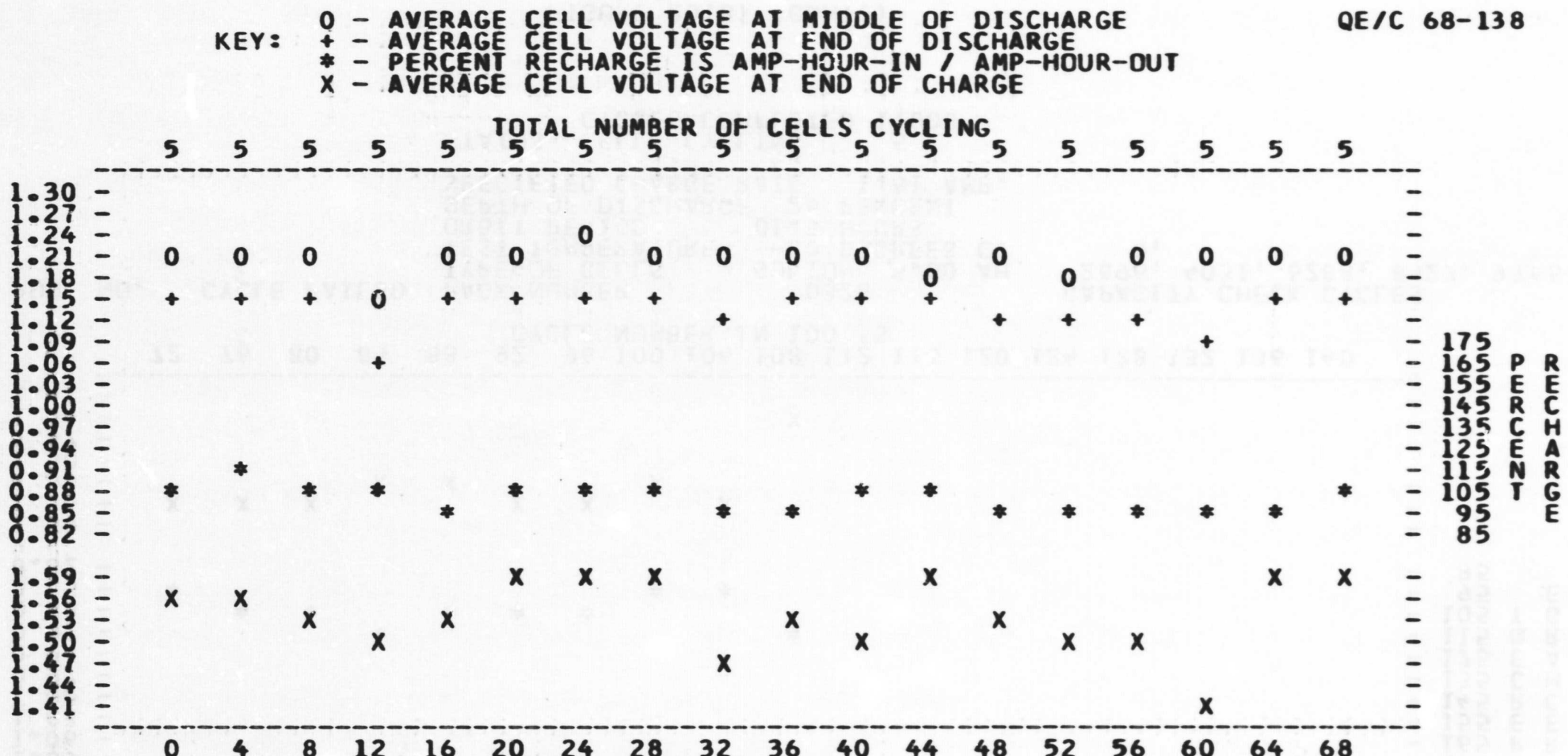

POS. NO. CYCLE FAILED

PACK NUMBER 044B
TYPE OF CELLS GULTON 5.60 AH
TEST TEMPERATURE -20 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 1.61 AMP.

STATUS CELLS CYCLING 5
CYCLES COMPLETED 11063

CAPACITY CHECK CYCLES
2696, 4047, 6304, 8606, 10239
0,

FIGURE 20(A)




POS. NO. CYCLE FAILED

PACK NUMBER 032B
TYPE OF CELLS GULTON 5.60 AH
TEST TEMPERATURE -20 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 1.61 AMP.

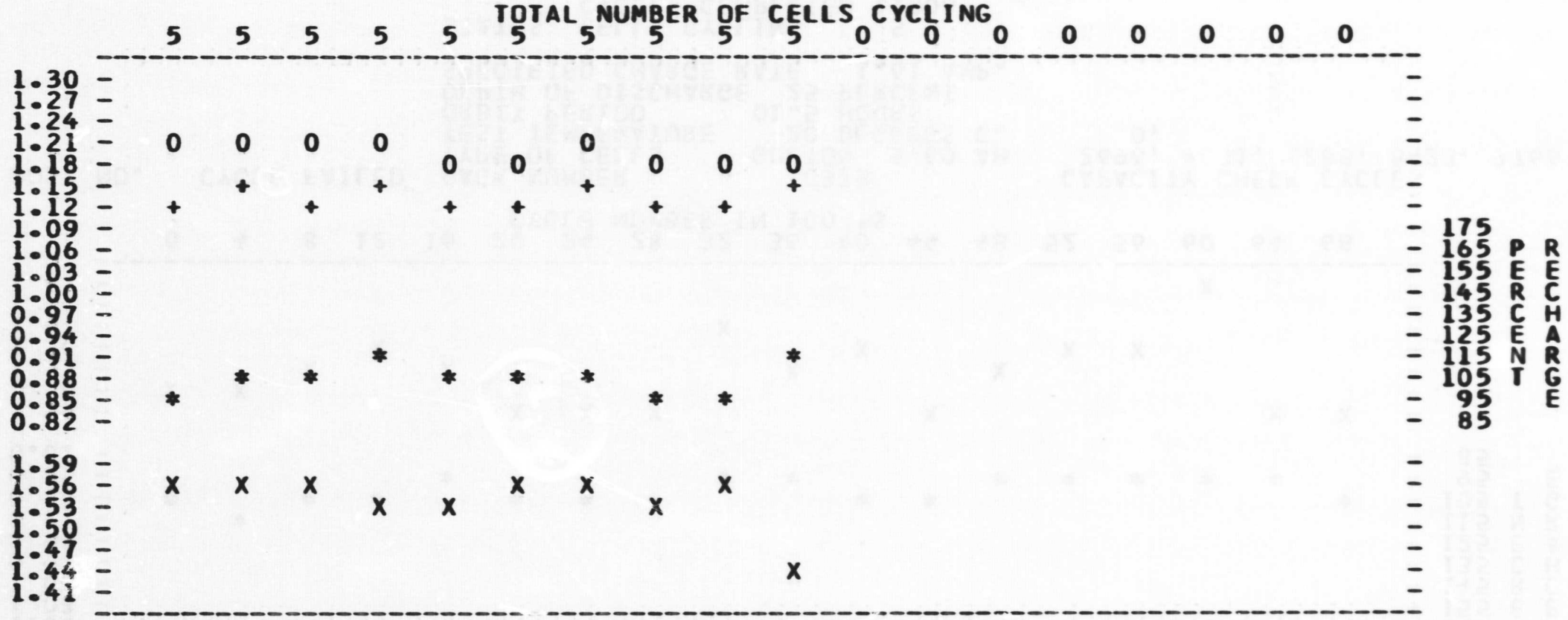
CAPACITY CHECK CYCLES
2696, 4031, 6288, 8423, 9766
0,

STATUS CELLS CYCLING 5
CYCLES COMPLETED 11008

FIGURE 20(B)

KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE

QE/C 68-138




POS. NO. CYCLE FAILED

PACK NUMBER 032B
TYPE OF CELLS GULTON 5.60 AH
TEST TEMPERATURE -20 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 1.61 AMP.

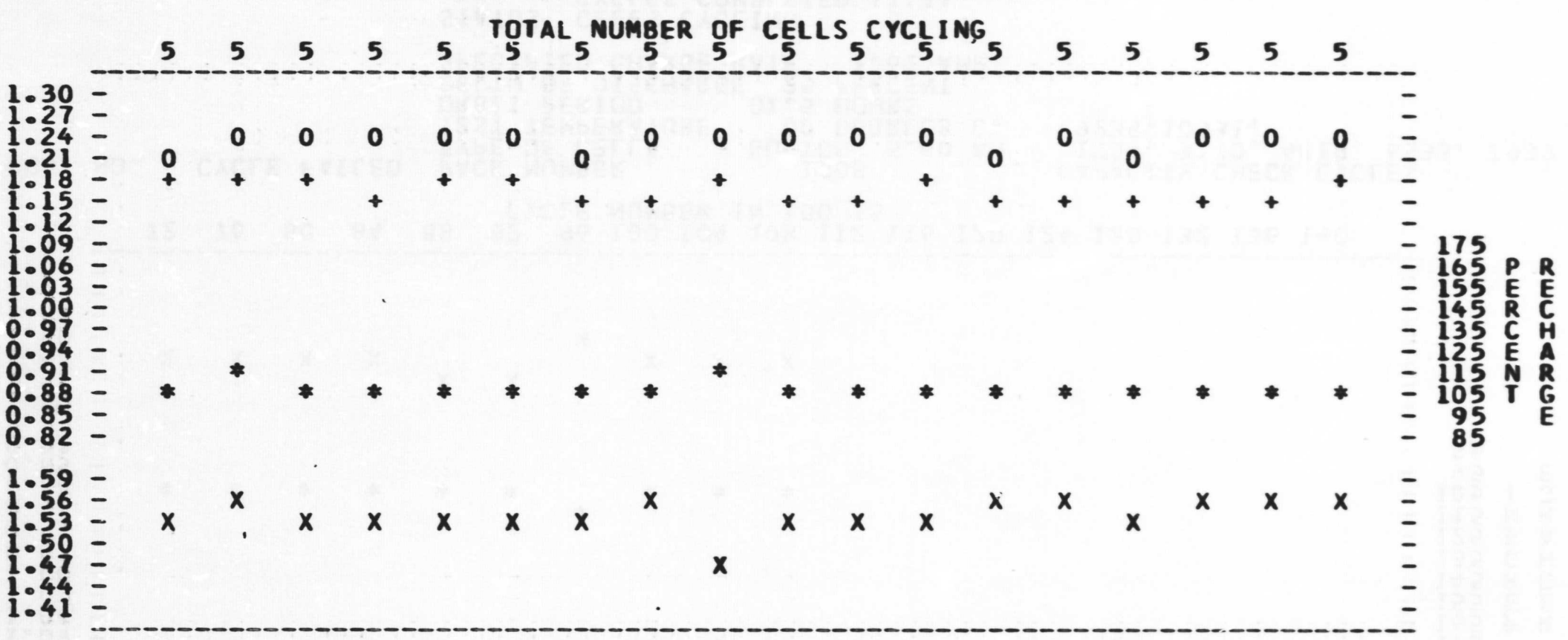
CAPACITY CHECK CYCLES
2696, 4031, [illegible]88, 8423, 9766
0,

STATUS CELLS CYCLING 5
CYCLES COMPLETED 11008

FIGURE 20(B) (CONTD)

KEY: 0 – AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ – AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* – PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X – AVERAGE CELL VOLTAGE AT END OF CHARGE

QE/C 68-138



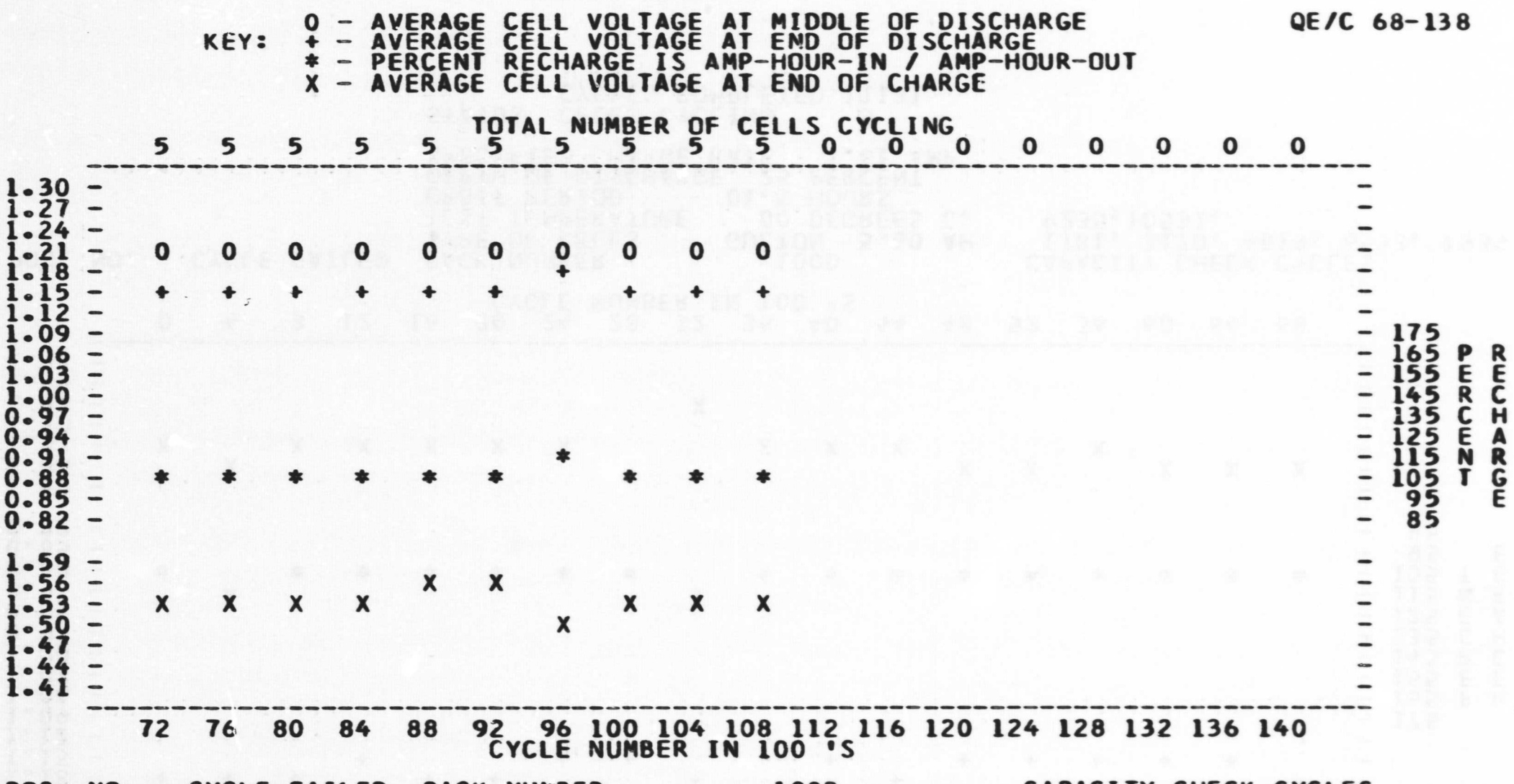

POS. NO. CYCLE FAILED

PACK NUMBER 100B
TYPE OF CELLS GULTON 5.60 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 1.61 AMP.

CAPACITY CHECK CYCLES
1781, 3170, 4819, 6533, 7939
9235,10531,

STATUS CELLS CYCLING 5
CYCLES COMPLETED 11131

FIGURE 20(C)




POS. NO. CYCLE FAILED

PACK NUMBER 1008
TYPE OF CELLS GULTON 5.60 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 1.61 AMP.

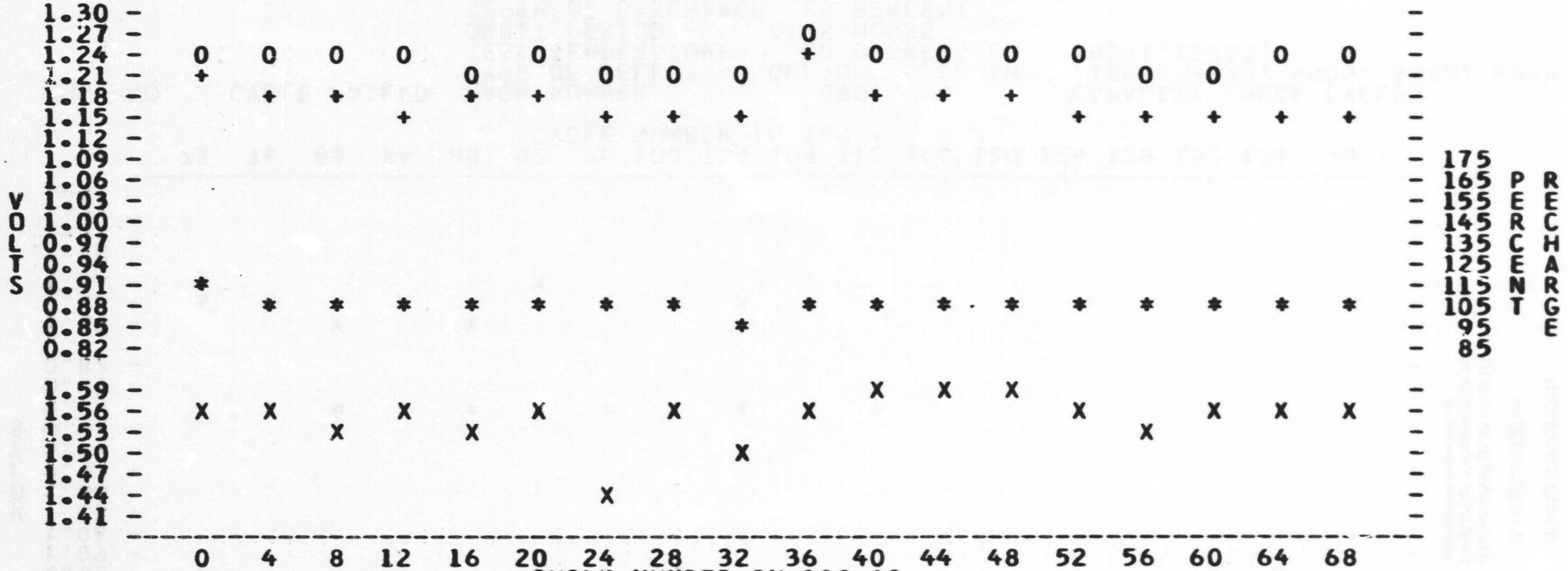
CAPACITY CHECK CYCLES
1701, 3170, 4819, 6533, 7939
9235,10531,

STATUS CELLS CYCLING 5
CYCLES COMPLETED 11131

FIGURE 20(C) (CONTD)

KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE

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POS. NO. CYCLE FAILED

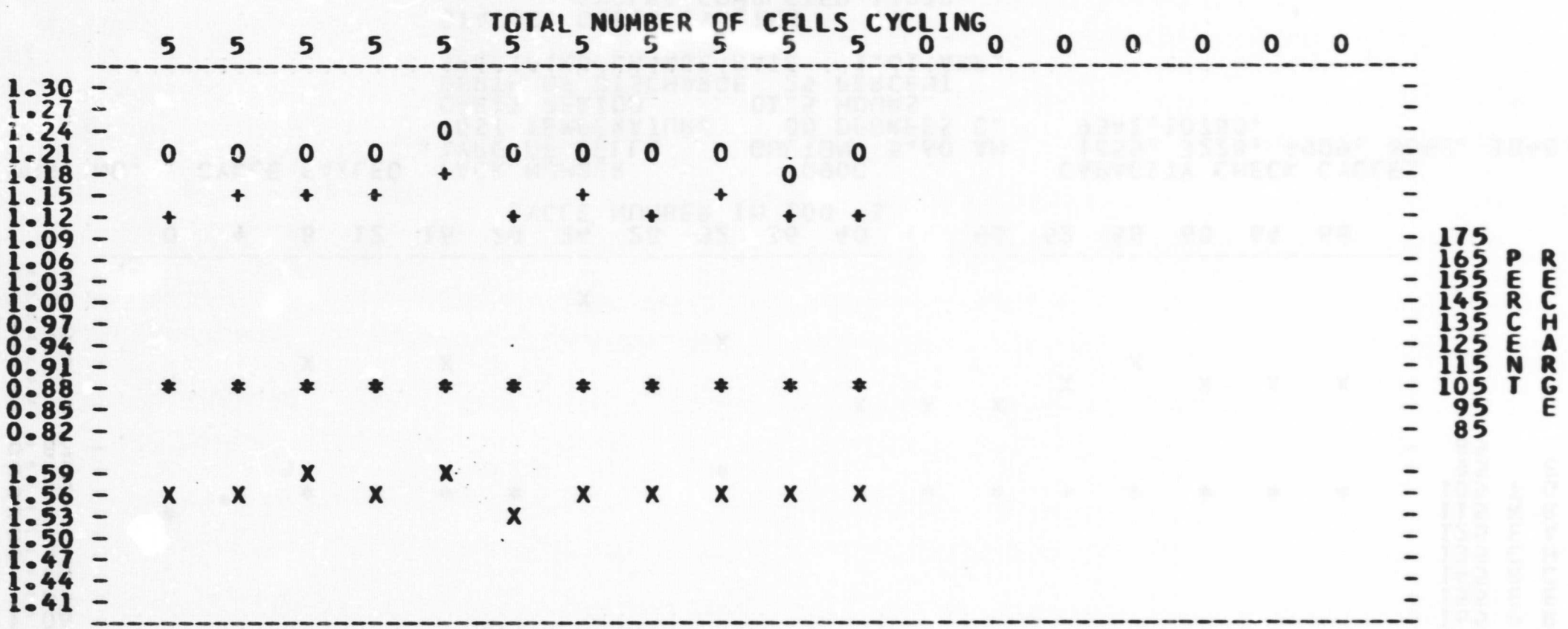
PACK NUMBER 090C
TYPE OF CELLS GULTON 5.60 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 1.61 AMP.

STATUS CELLS CYCLING 5
CYCLES COMPLETED 11238

CAPACITY CHECK CYCLES
1855, 3228, 4909, 6642, 8048
9341,10780,

FIGURE 20(D)

KEY: 0 – AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ – AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* – PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X – AVERAGE CELL VOLTAGE AT END OF CHARGE




POS. NO. CYCLE FAILED

PACK NUMBER 090C
TYPE OF CELLS GULTON 5.60 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 1.61 AMP.

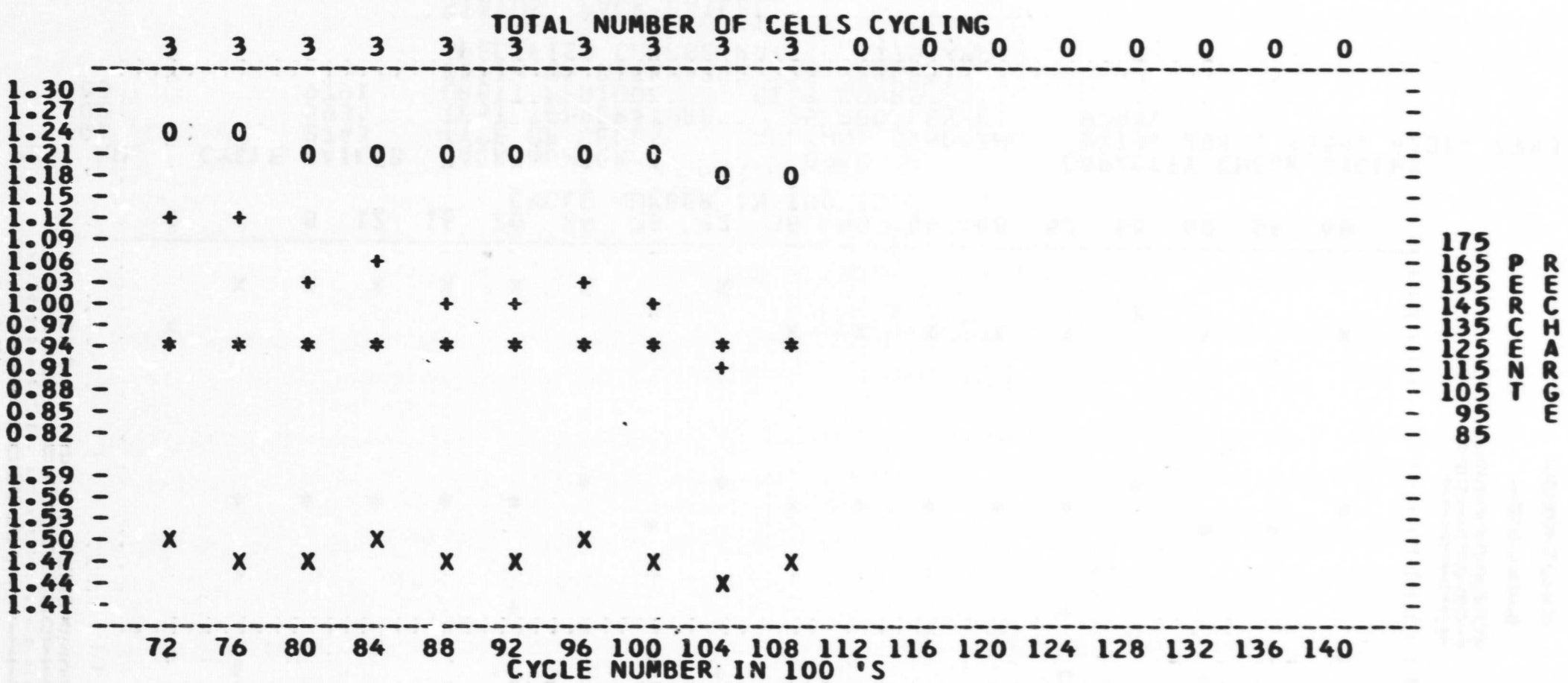
STATUS CELLS CYCLING 5
CYCLES COMPLETED 11238

CAPACITY CHECK CYCLES
1855, 3228, 4909, 6642, 8048
9341,10780,

FIGURE 20(D) (CONTD)

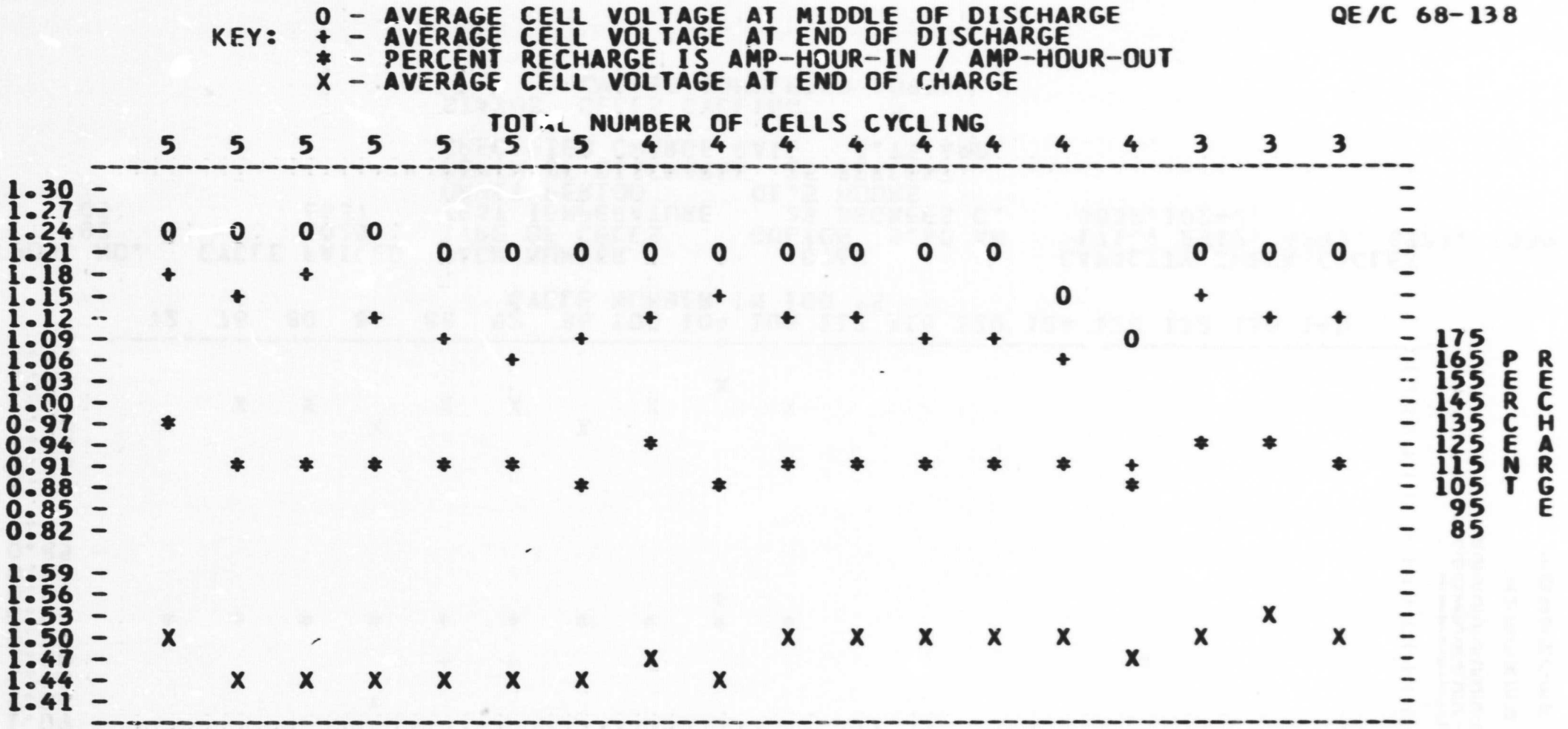
KEY: 0 – AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ – AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* – PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X – AVERAGE CELL VOLTAGE AT END OF CHARGE

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| POS. NO. | CYCLE FAILED | PACK NUMBER | 076B | CAPACITY CHECK CYCLES |
|---|---|---|---|---|
| 02 | 2025 | TYPE OF CELLS | GULTON 5.60 AH | 1714, 2912, 4291, 6327, 7539 |
| 05 | 6637 | TEST TEMPERATURE | 25 DEGREES C. | 8832,10242, |
| | | ORBIT PERIOD | 01.5 HOURS | |
| | | DEPTH OF DISCHARGE | 25 PERCENT | |
| | | SPECIFIED CHARGE RATE | 1.75 AMP. | |
| | | STATUS CELLS CYCLING | 3 | |
| | | CYCLES COMPLETED | 10954 | |

FIGURE 20(E)




| POS. NO. | CYCLE FAILED |
|---|---|
| 01 | 2743 |
| 02 | 5934 |
| 03 | 9791 |

PACK NUMBER 096C
TYPE OF CELLS GULTON 5.60 AH
TEST TEMPERATURE 25 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 1.75 AMP.

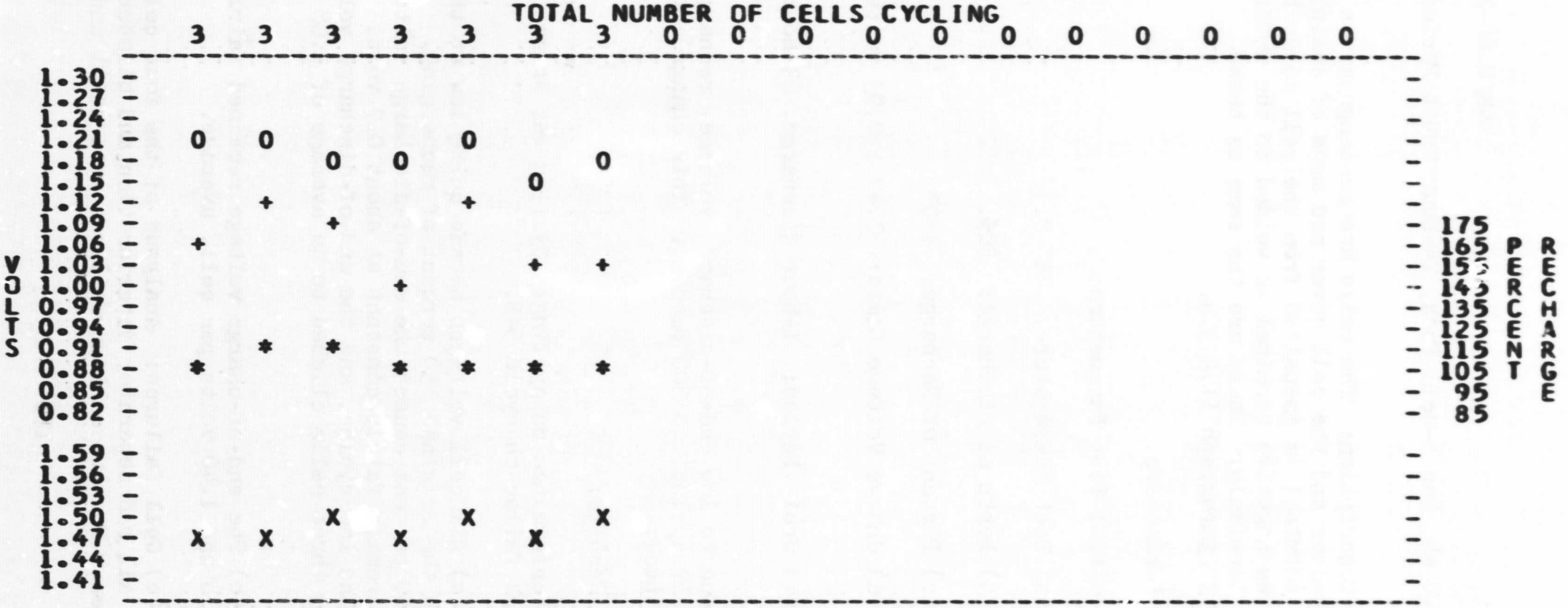
CAPACITY CHECK CYCLES
1719, 2983, 4359, 6237, 7753
9048,

STATUS PACK FAILED
ON CYCLE NUMBER 9791

FIGURE 20(F)

KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE

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| POS. NO. | CYCLE FAILED | | | CAPACITY CHECK CYCLES |
|---|---|---|---|---|
| 01 | 2743 | PACK NUMBER | 096C | 1719, 2983, 4359, 6237, 7753 |
| 02 | 5934 | TYPE OF CELLS | GULTON 5.60 AH | 9048, |
| 03 | 9791 | TEST TEMPERATURE | 25 DEGREES C. | |
| | | ORBIT PERIOD | 01.5 HOURS | |
| | | DEPTH OF DISCHARGE | 25 PERCENT | |
| | | SPECIFIED CHARGE RATE | 1.75 AMP. | |

STATUS PACK FAILED
ON CYCLE NUMBER 9791

FIGURE 20(F) (CONTD)

5. Gulton 6.0 ah, One 5-cell Pack, 24-hour Orbit Period (Pack 79A):

a. Cell Description: The cells are rectangular in shape. The cell container and the cell cover are made of stainless steel. The positive terminal is insualted from the cell cover by a ceramic seal, while the negative terminal is welded to the cover. Both are solder type terminals. These are the same as those described in section I, paragraph II.A.3.a.

b. Test Parameters:

(1) Initial Test Parameters:

(a) Test Temperature: 25° C.

(b) Depth of Discharge: 50%.

(c) Percent of Recharge: 150%.

(d) Charge Voltage Limit: 1.49 ± 0.03 volts per cell, average.

(e) Orbit Period: 1-hour discharge, 23-hour charge.

(2) Due to low end-of-discharge voltage, recharging was increased, after 57 cycles, to 200 percent. This change improved the operation of the pack.

c. Test Results:

(1) Performance on cycling: Cycling was started in March 1964. This pack failed on cycle 545.

(a) All cell voltages became quite low at the end of discharge with the original 150 percent of recharging. Increasing this to 200 percent caused the end-of-discharge voltages of all five cells to remain fairly constant at about 0.9 volt. Two cells failed at 149 and 168 cycles, and the end-of-discharge voltages of the remaining three cells climbed to an average of 1.08 volts per cell.

(b) The end-of-charge voltage remained fairly constant, between 1.38 and 1.40 volts per cell, average.

(c) Cell failures: Analyses of the four cell failures showed that all had separator deterioration and blistering on the positive plates. The two earlier failures were still under

high pressure when opened. The last two failures had pinpoint migration which caused shorts through the separator.

(2) Capacity checks: The ampere-hour capacities on the preconditioning and capacity check cycles are as follows:

| Precon-ditioning | 88 Days Discharge #1 | #2 | 176 Days Discharge #1 | #2 |
|---|---|---|---|---|
| 6.60 | 2.88 | 3.55 | 3.15 | 4.40 |

| 264 Days Discharge #1 | #2 | 352 Days Discharge #1 | #2 | 440 Days Discharge #1 | #2 |
|---|---|---|---|---|---|
| 2.90 | 4.25 | 2.95 | 4.05 | 2.85 | 3.50 |

6. Gulton 6.0 ah (Improved), Three 5-cell Packs, 1.5-hour Cycle Period:

a. Cell Description: The cells are rectangular in shape. The cell container and the cell cover are made of stainless steel. The positive terminal is insulated from the cell cover by a ceramic seal, while the negative terminal is welded to the cover. Both are solder type terminals. These are the same as those described in section I, paragraph II.A.3.a., except that the silver braze of the ceramic seal is nickel plated to prevent internal cell shorting by silver migration to the cover.

b. Test Parameters:

| Pack Number | Test Temperature | Percent Depth of Discharge | Percent of Recharge | Charge Voltage Limit, Per Cell |
|---|---|---|---|---|
| 13B | 0° C | 25 | 115 | 1.55 ± 0.03 |
| 18B | 25° C | 40 | 125 | 1.49 ± 0.03 |
| 38B | 40° C | 25 | 160 | 1.45 ± 0.03 |

c. Test Results:

(1) Performance on cycling: (Figure 21.) Cycling was started in February 1965. These packs have completed from 5,766 to 15,904 cycles with six cell failures.

(a) The cells operating at 0° C showed a very high end-of-discharge voltage, and the end-of-charge voltage showed a slight tendency toward higher values. However, at 25° C and at 40° C, the end-of-discharge voltage was much lower and more variable.

(b) There were no cell failures at 0° C but both packs operating at the higher temperatures have failed. Three of the six failed cells had ceramic shorts. Migration of negative plate material and separator deterioration were present in all failed cells. In one cell at 40° C, separator deterioration was so severe that the positive and negative plates shorted together. There have been no signs of leakage to date.

(2) Capacity checks: The ampere-hour capacities on the preconditioning and capacity check cycles are as follows:

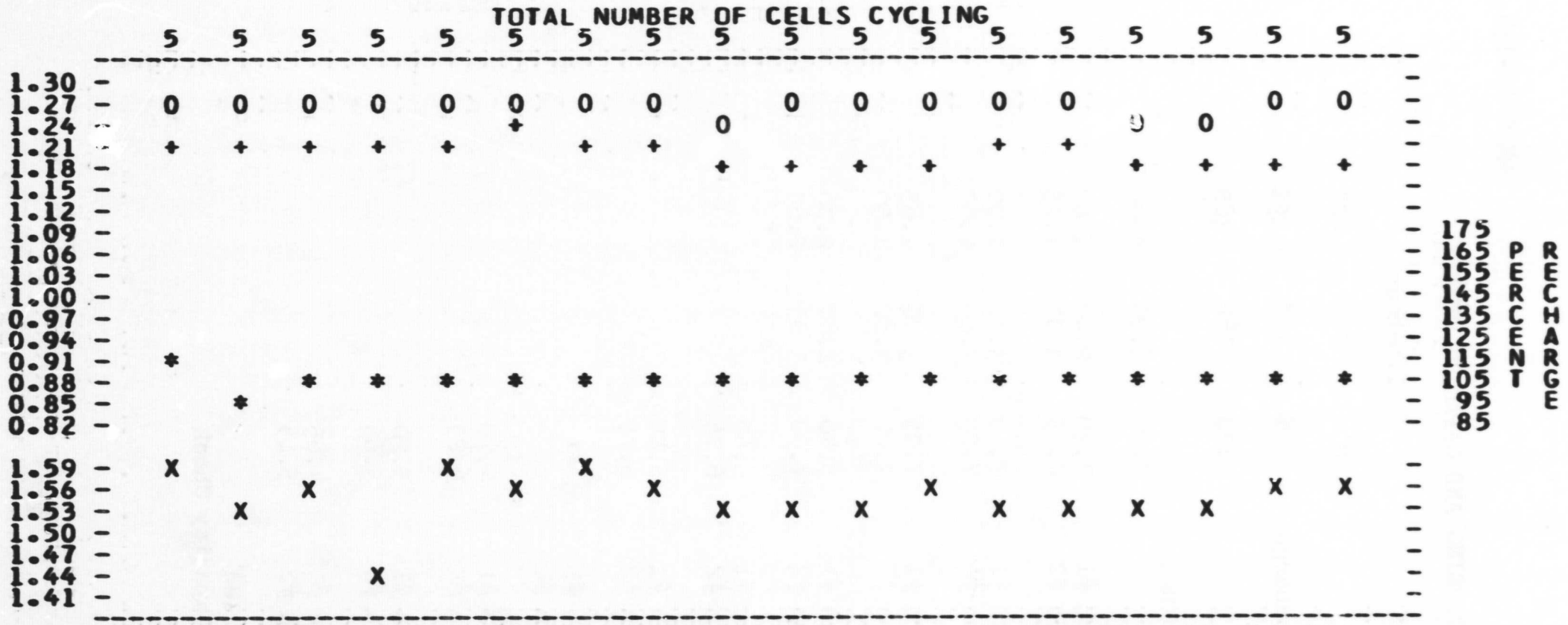
## PRECONDITIONING AND CAPACITY CHECKS

| Orbit Period | | 1.5-hour | | |
|---|---|---|---|---|
| Temperature | | 0° | 25° | 40° |
| Depth of Discharge | | 25% | 40% | 25% |
| Pack Number | | 13B | 18B | 38B |
| Preconditioning Capacity | | 7.30 | 6.90 | 5.00 |
| 88 Days | Disch #1 | 7.30 | 2.40 | 1.60 |
| | Disch #2 | 6.95 | 3.00 | 1.75 |
| 176 Days | Disch #1 | 7.10 | 3.10 | 1.90 |
| | Disch #2 | 7.25 | 3.60 | 2.00 |
| 264 Days | Disch #1 | 7.05 | 3.20 | 1.85 |
| | Disch #2 | 7.20 | 3.80 | 1.50 |
| 352 Days | Disch #1 | 5.40 | 2.80 | 2.00 |
| | Disch #2 | 7.00 | 3.05 | 2.80 |
| | | | * | * |
| 440 Days | Disch #1 | 6.60 | | |
| | Disch #2 | 6.75 | | |
| 528 Days | Disch #1 | 6.55 | | |
| | Disch #2 | 6.75 | | |
| 616 Days | Disch #1 | ** | | |
| | Disch #2 | | | |
| 704 Days | Disch #1 | 4.70 | | |
| | Disch #2 | 6.25 | | |
| 792 Days | Disch #1 | 5.20 | | |
| | Disch #2 | 5.65 | | |
| 880 Days | Disch #1 | 4.85 | | |
| | Disch #2 | 5.15 | | |

* Pack Failed
** Missed Capacity Check

KEY: 0 – AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ – AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* – PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X – AVERAGE CELL VOLTAGE AT END OF CHARGE

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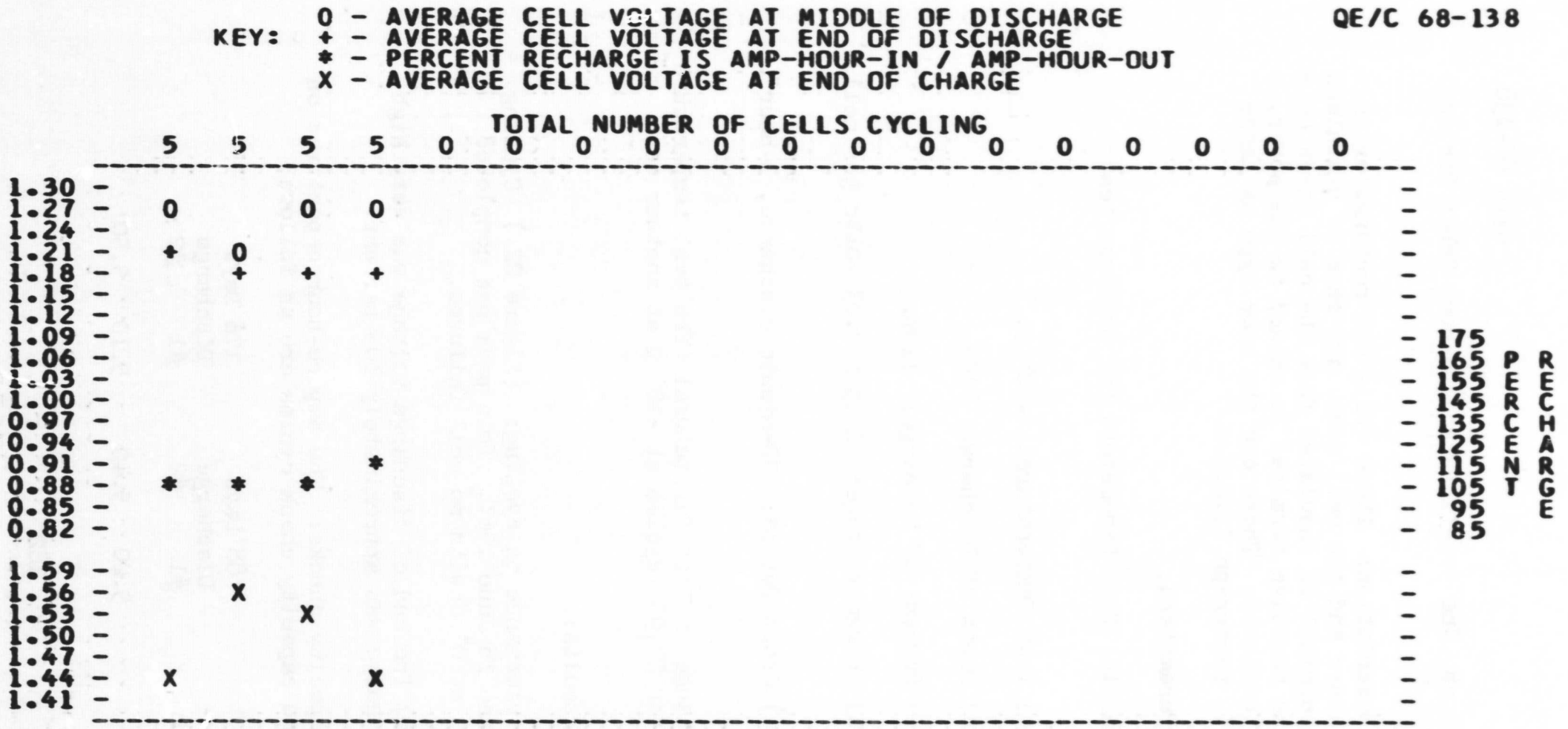

POS. NO. CYCLE FAILED

PACK NUMBER 0138
TYPE OF CELLS GULTON 6.00 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 1.73 AMP.

STATUS CELLS CYCLING 5
CYCLES COMPLETED 15904

CAPACITY CHECK CYCLES
1381, 3080, 4367, 6159, 7075
8048,13253,14408,15813,

FIGURE 21




POS. NO. CYCLE FAILED

PACK NUMBER 013B
TYPE OF CELLS GULTON 6.00 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 1.73 AMP.

CAPACITY CHECK CYCLES
1381, 3080, 4367, 6159, 7075
8048,13253,14408,15813,

STATUS CELLS CYCLING 5
CYCLES COMPLETED 15904

FIGURE 21 (CONTD)

7. Gulton 6.0 ah, One 5-cell Pack, 1.5-hour Orbit Period (Pack 61B):

a. ell Description: These cells are rectangular in shape. The cell container and the cell cover are made of stainless steel. The positive terminal is insulated from the cell cover by a ceramic seal, while the negative terminal is welded to the cover. Both are solder type terminals. These are the same type as those described in section I, paragraph II.A.3.a.

b. Test Parameters:

(1) Initial Test Parameters (at previous test facility):

(a) Test Temperature: -10° C.

(b) Depth of Discharge: 10%.

(c) Percent of Recharge: 110%.

(d) Charge Voltage: 1.55 ± 0.03 volts per cell, average.

(e) Orbit Period. 30-minute discharge, 1-hour charge.

(2) Change in Test Parameters: The test temperature was raised to 0° C after 22,900 cycles at -10° C at another test facility.

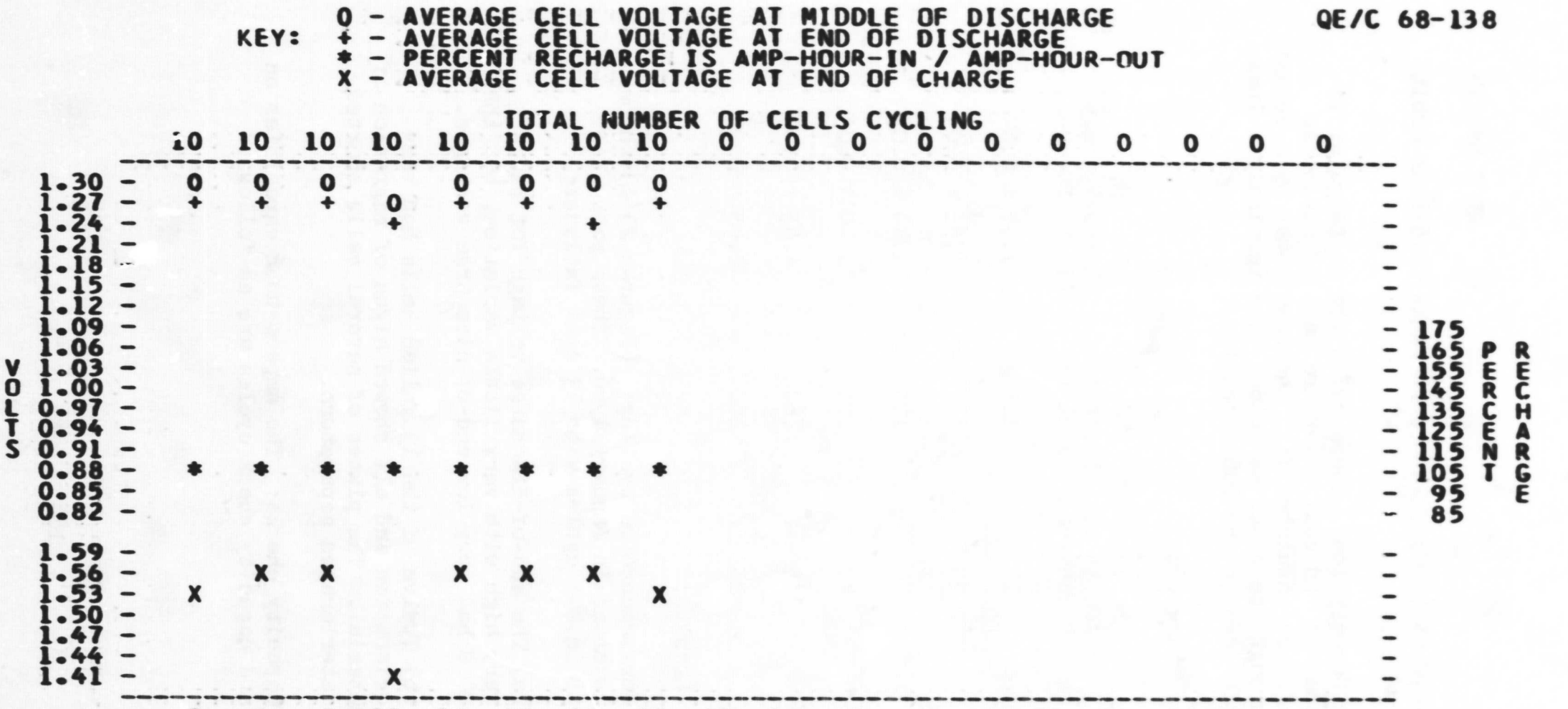
c. Test Results:

(1) Performance on cycling: (Figure 22.) Cycling was started at NAD Crane in June 1967. This pack has completed 2942 additional cycles at 0° C with no cell failures.

(a) The end of discharge voltage was very high and the percent of recharge was approximately 105 percent.

(2) Capacity checks: The ampere-hour capacities on the preconditioning and capacity check cycles are as follows:

| Precon-ditioning | 88 Days Discharge #1 | 88 Days Discharge #2 | 176 Days Discharge #1 | 176 Days Discharge #2 |
|---|---|---|---|---|
| 5.30 | 5.20 | 5.40 | 5.10 | 5.50 |




POS. NO. CYCLE FAILED

PACK NUMBER 061B
TYPE OF CELLS GULTON 6.00 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 10 PERCENT
SPECIFIED CHARGE RATE 0.66 AMP.

CAPACITY CHECK CYCLES
1444, 2708,

STATUS CELLS CYCLING 10
CYCLES COMPLETED 2942

THIS PACK HAD RECIEVED 22900 CYCLES AT 10 PERCENT DEPTH OF DISCHARGE AND AT -10 DEGREES CENTIGRADE BEFORE STARTING CYCLE 1 AT N.A.D. CRANE.

FIGURE 22

8. Gulton 12.0 ah (OGO), Six 5-cell Packs, 1.5-hour Orbit Period:

a. Cell Description: These cells are rectangular in shape. The cell container and cell cover are made of stainless steel. Both terminals are insulated from the cell cover by a ceramic seal and protrude through the cover as solder type terminals. These cells were designed for use in the OGO satellite.

b. Test Parameters:

| Pack Number | Test Temperature | Percent Depth of Discharge | Percent of Recharge | Charge Voltage Limit, Per Cell |
|---|---|---|---|---|
| 16B | 0° C | 15 | 115 | 1.55 ± 0.03 |
| 101B | 0° C | 25 | 115 | 1.55 ± 0.03 |
| 27B | 25° C | 25 | 125 | 1.49 ± 0.03 |
| 96B | 25° C | 40 | 125 | 1.49 ± 0.03 |
| 78A | 40° C | 15 | 160 | 1.45 ± 0.03 |
| 90B | 40° C | 25 | 160 | 1.45 ± 0.03 |

c. Test Results:

(1) Performance on cycling: (Figures 23(A) through 23(D).) Cycling was started in January 1966. These packs have completed from 5124 to 16,695 cycles with 13 cell failures.

(a) The end-of-discharge voltage for packs cycling at 0° C was very high with very little variation, but the packs at 25° C and 40° C had very low end-of-discharge voltages.

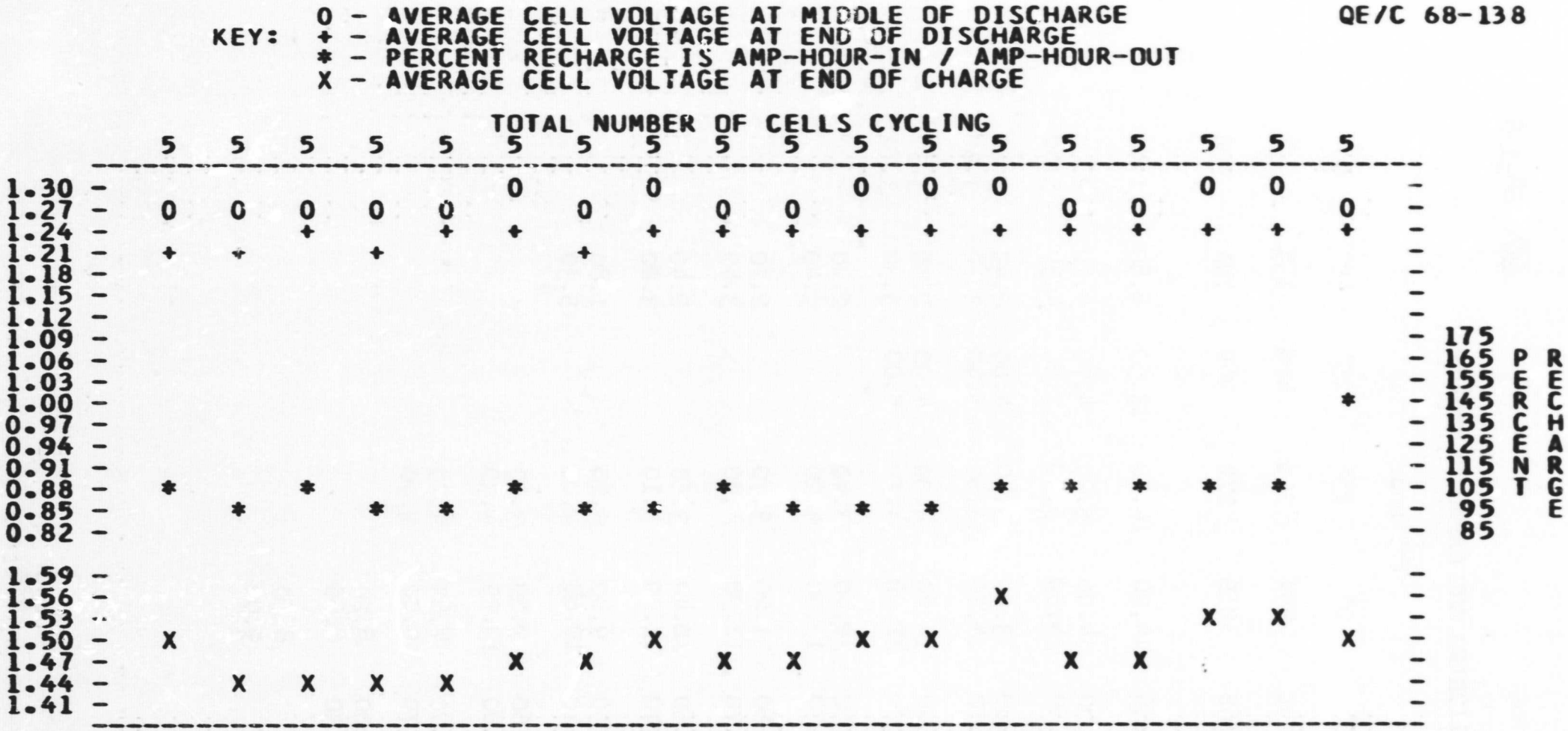
(b) Twelve of the 13 failed cells had very severe separator deterioration and all showed signs of migration of the negative plate material. The plates of several cells shorted together because of deteriorated separators.

(2) Capacity checks: The ampere-hour capacities on the preconditioning and capacity check cycles are as follows:

## PRECONDITIONING AND CAPACITY CHECKS

| Orbit Period | | 1.5-hour | | | | | |
|---|---|---|---|---|---|---|---|
| Temperature | | 0° | 0° | 25° | 25° | 40° | 40° |
| Depth of Discharge | | 15% | 25% | 25% | 40% | 15% | 25% |
| Pack Number | | 16B | 101B | 27B | 96B | 78A | 90B |
| Preconditioning Capacity | | 14.86 | 14.20 | 14.10 | 13.30 | 6.80 | 11.40 |
| 88 Days | Disch #1 | 14.00 | 14.00 | 5.20 | 4.70 | 4.10 | 2.90 |
| | Disch #2 | 13.50 | 14.50 | 5.90 | 3.20 | 4.30 | 5.40 |
| 176 Days | Disch #1 | 13.60 | 13.90 | 3.40 | 4.60 | 2.40 | 3.50 |
| | Disch #2 | 14.10 | 14.40 | 3.50 | 5.40 | 3.10 | 3.60 |
| 264 Days | Disch #1 | 13.90 | 14.20 | 4.00 | 4.90 | 2.90 | 3.30 |
| | Disch #2 | 14.20 | 12.90 | 4.10 | 5.00 * | 3.30 | 3.70 * |
| 352 Days | Disch #1 | 12.80 | 12.40 | 3.40 | | 2.90 | |
| | Disch #2 | 13.70 | 13.00 | 4.20 | | 3.40 | |
| 440 Days | Disch #1 | 12.60 | 11.20 | 3.70 | | 2.70 | |
| | Disch #2 | 13.70 | 11.90 | 4.80 | | 3.40 | |
| 528 Days | Disch #1 | 10.60 | 10.40 | 3.60 | | 2.40 | |
| | Disch #2 | 12.40 | 11.00 | 5.10 | | 3.20 | |
| 616 Days | Disch #1 | 11.50 | 9.80 | 3.20 | | 1.80 | |
| | Disch #2 | 13.10 | 10.60 | 4.00 | | 5.30 * | |
| 704 Days | Disch #1 | 11.60 | 9.20 | 3.00 | | | |
| | Disch #2 | 12.80 | 10.20 | 4.30 | | | |
| 792 Days | Disch #1 | 11.20 | 7.83 | 2.70 | | | |
| | Disch #2 | 12.70 | 9.00 | 3.90 * | | | |
| 880 Days | Disch #1 | 12.00 | 8.20 | | | | |
| | Disch #2 | 12.30 | 8.88 | | | | |
| 968 Days | Disch #1 | | 8.80 | | | | |
| | Disch #2 | | 9.00 | | | | |

* Pack Failed




POS. NO. CYCLE FAILED

PACK NUMBER 016B
TYPE OF CELLS GULTON 12.00 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 15 PERCENT
SPECIFIED CHARGE RATE 2.07 AMP.

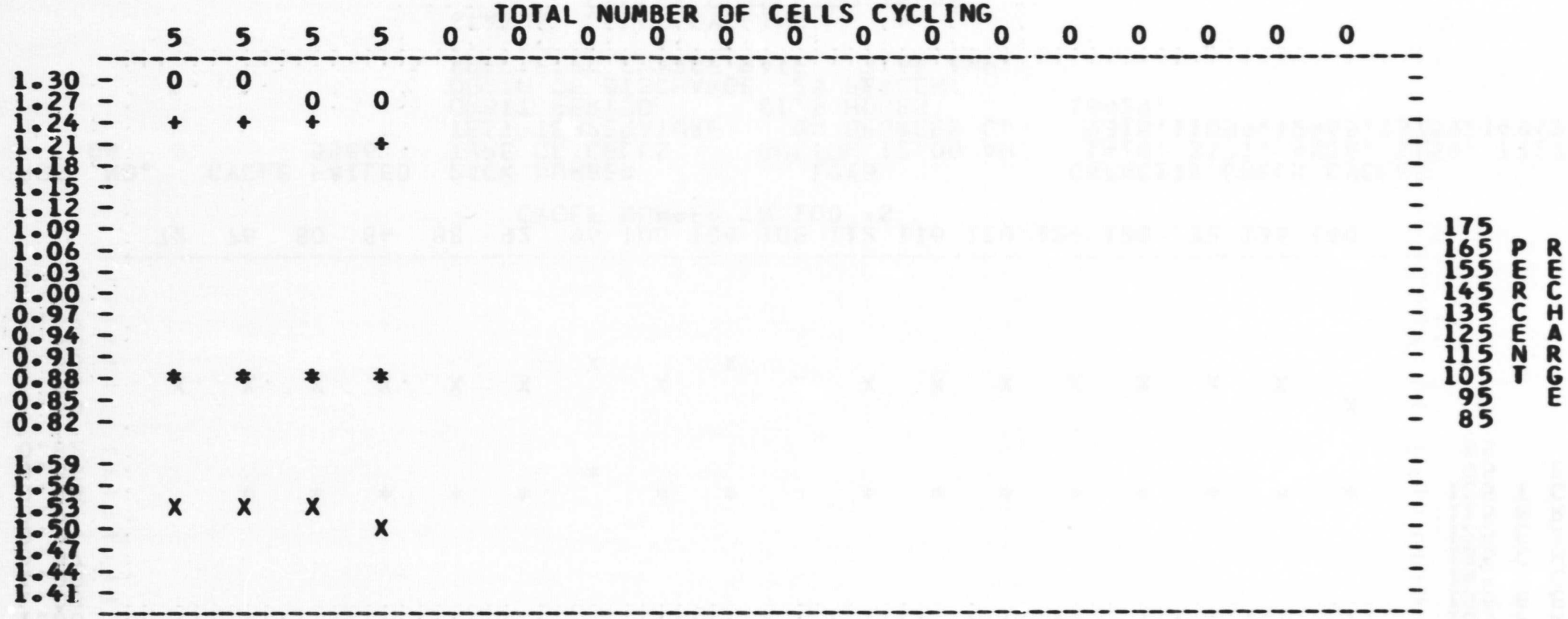
STATUS CELLS CYCLING 5
CYCLES COMPLETED 15859

CAPACITY CHECK CYCLES
1407, 2867, 4078, 5628, 7253
8572,10557,11964,12138,13401
14955,

FIGURE 23(A)

KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE

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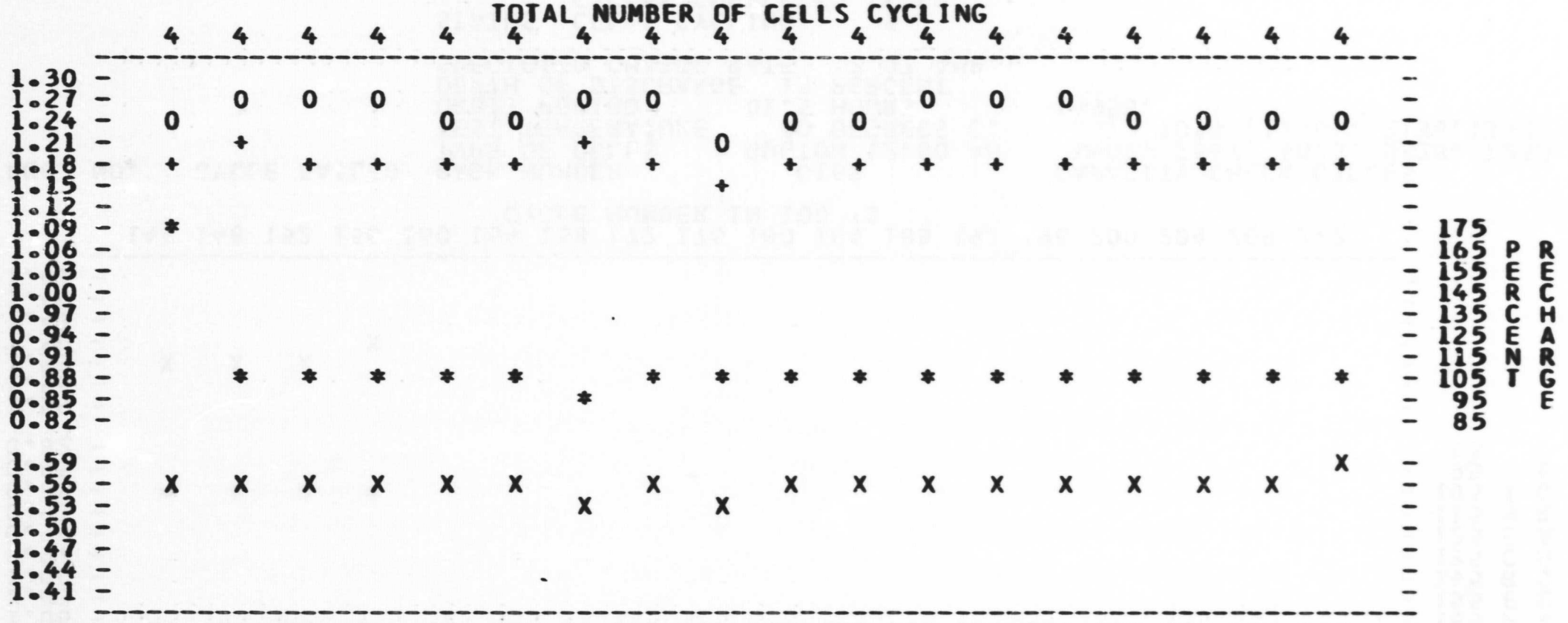

| POS. NO. | CYCLE FAILED | | |
|---|---|---|---|
| | | PACK NUMBER | 016B |
| | | TYPE OF CELLS | GULTON 12.00 AH |
| | | TEST TEMPERATURE | 00 DEGREES C. |
| | | ORBIT PERIOD | 01.5 HOURS |
| | | DEPTH OF DISCHARGE | 15 PERCENT |
| | | SPECIFIED CHARGE RATE | 2.07 AMP. |
| | | STATUS | CELLS CYCLING 5 |
| | | | CYCLES COMPLETED 15859 |

CAPACITY CHECK CYCLES
1407, 2867, 4078, 5628, 7253
8572,10557,11964,12138,13401
14955,

FIGURE 23(A) (CONTD)

KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE

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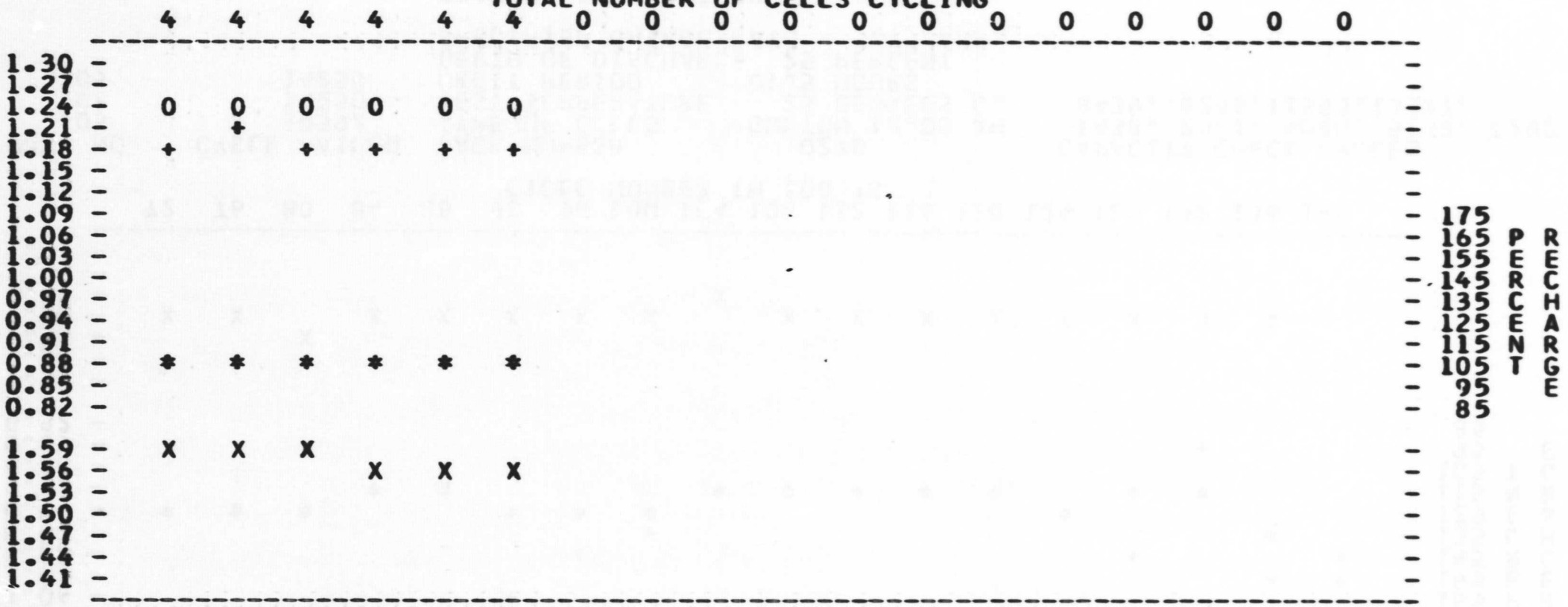

| POS. NO. | CYCLE FAILED | | | CAPACITY CHECK CYCLES |
|---|---|---|---|---|
| 04 | 5586 | PACK NUMBER | 101B | 1416, 3371, 4526, 6159, 7727 |
| | | TYPE OF CELLS | GULTON 12.00 AH | 9315,11059,12465,13759,14942 |
| | | TEST TEMPERATURE | 00 DEGREES C. | 16429, |
| | | ORBIT PERIOD | 01.5 HOURS | |
| | | DEPTH OF DISCHARGE | 25 PERCENT | |
| | | SPECIFIED CHARGE RATE | 3.45 AMP. | |

STATUS CELLS CYCLING 4
CYCLES COMPLETED 16695

FIGURE 23(B)

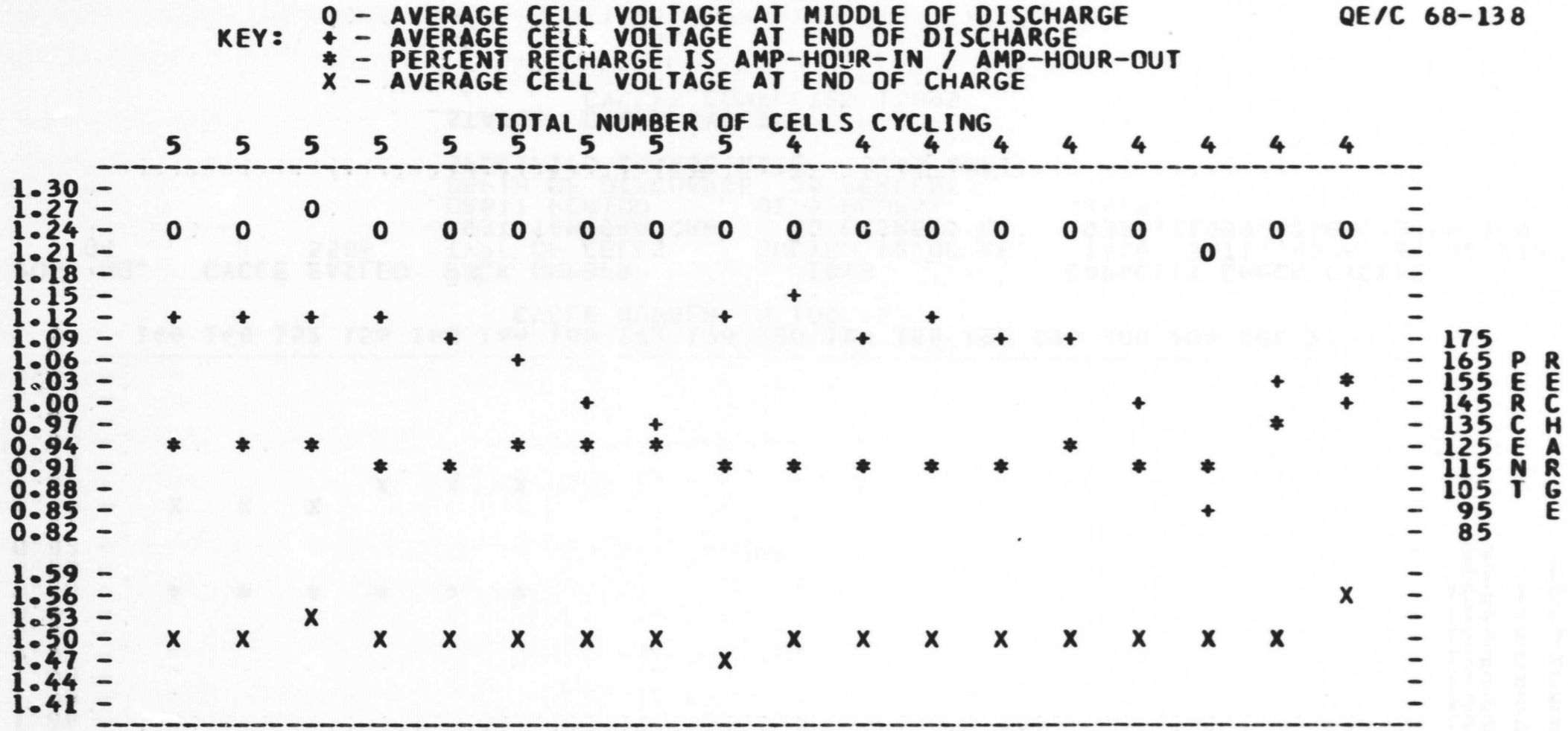
KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE

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| POS. NO. | CYCLE FAILED | PACK NUMBER | 101B | CAPACITY CHECK CYCLES |
|---|---|---|---|---|
| 04 | 5586 | TYPE OF CELLS | GULTON 12.00 AH | 1416, 3371, 4526, 6159, 7727 |
| | | TEST TEMPERATURE | 00 DEGREES C. | 9315,11059,12465,13759,14942 |
| | | ORBIT PERIOD | 01.5 HOURS | 16429, |
| | | DEPTH OF DISCHARGE | 25 PERCENT | |
| | | SPECIFIED CHARGE RATE | 3.45 AMP. | |
| | | STATUS | CELLS CYCLING 4 | |
| | | | CYCLES COMPLETED 16695 | |

FIGURE 23(B) (CONTD)




| POS. NO. | CYCLE FAILED |
|---|---|
| 03 | 10592 |
| 02 | 14250 |
| 05 | 14250 |

PACK NUMBER 027B
TYPE OF CELLS GULTON 12.0C AH
TEST TEMPERATURE 25 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 3.75 AMP.

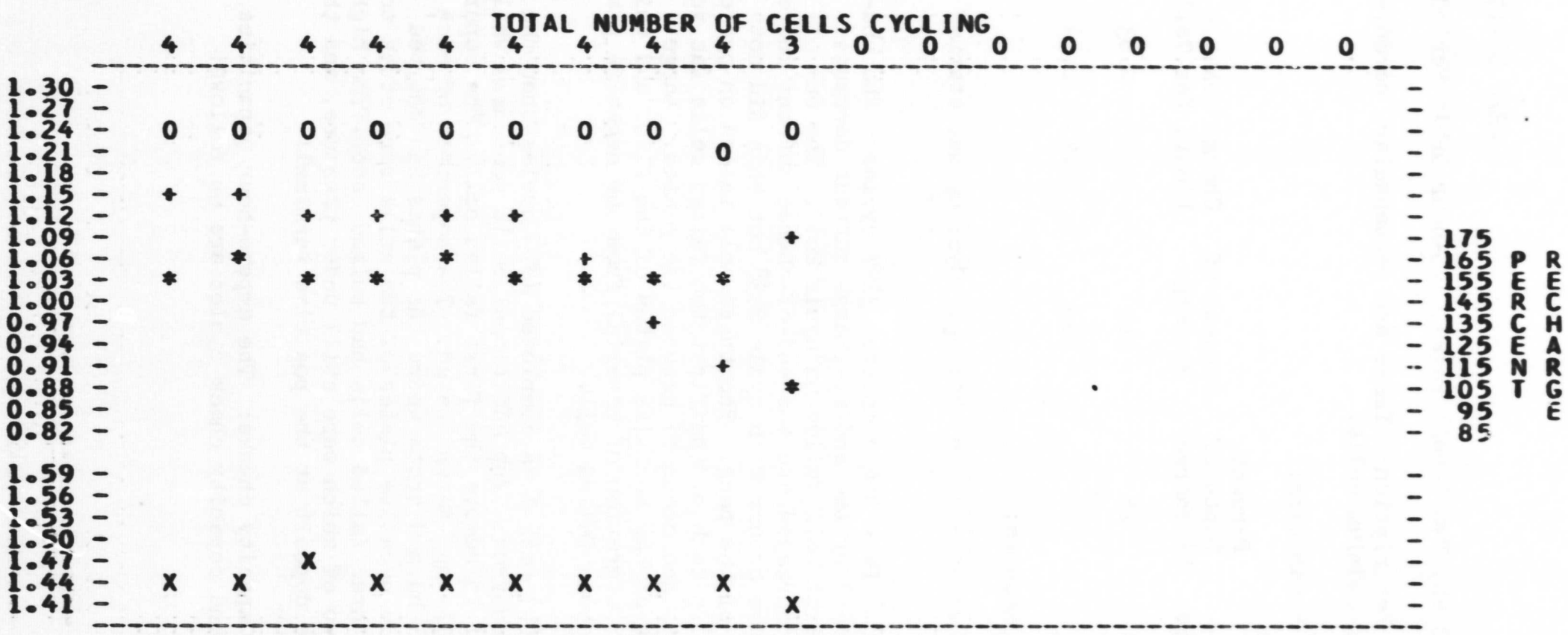
STATUS PACK FAILED
ON CYCLE NUMBER 14250

CAPACITY CHECK CYCLES
1438, 2921, 4080, 5739, 7292
8439,10206,11553,13327,

FIGURE 23(C)

KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE

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| POS. NO. | CYCLE FAILED |
|---|---|
| 04 | 1307 |
| 03 | 10426 |
| 02 | 11081 |

PACK NUMBER 078A
TYPE OF CELLS GULTON 12.00 AH
TEST TEMPERATURE 40 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 15 PERCENT
SPECIFIED CHARGE RATE 2.88 AMP.

CAPACITY CHECK CYCLES
1528, 3182, 4423, 6128, 7407
8872,10488,

STATUS PACK FAILED
ON CYCLE NUMBER 11081

FIGURE 23(D)

9. Gulton 50 ah, Two 5-cell Packs, 1.5-hour Orbit Period:

a. Cell Description: These are rectangular, hermetically sealed, nickel-cadmium cells.

b. Test Parameters:

| Pack Number | Test Temperature | Percent Depth of Discharge | Percent of Recharge | Charge Voltage Limit, Per Cell |
|---|---|---|---|---|
| 95A | 0° C | 25 | 115 | 1.55 ± 0.03 |
| 123A | 40° C | 25 | 160 | 1.45 ± 0.03 |

c. Test Results:

(1) Performance on cycling: Cycling was started in June 1964.

(a) Pack 95A completed 3227 cycles. The end-of-charge voltage increased or the end-of-charge current decreased steadily until the first cell failed on cycle 2643. The end-of-charge voltage then decreased and the end-of-charge current increased. The second cell failure occurred on cycle 2938 but this did not affect the operation of the pack. The third cell failed on cycle 3227. The separator in each of the first two failed cells was very dry and short circuits had occurred between the plates. Large blisters were present on the positive plates of the first and third failed cells. Slight migration of material from the negative plates was evident in the second failed cell.

(b) Pack 123A completed 1873 cycles when the first cell failure occurred. Two additional cells went dead while the pack was shut off to remove the first failed cell. The separators of all three cells had deteriorated. The separator of each of two cells had several burned spots where the plates had shorted together. The outside negative plates of two cells were stuck to the cell case. All three failed cells had bulged cases from high internal pressure; two of which were still under pressure, and the third had a carbonate deposit at the positive terminal.

(2) Capacity checks: The ampere-hour capacities on the preconditioning and capacity check cycles are as follows:

(a) Pack 95A:

| Preconditioning | 88 Days Discharge #1 | 88 Days Discharge #2 | 176 Days Discharge #1 | 176 Days Discharge #2 |
|---|---|---|---|---|
| 54.6 | 57.5 | 59.6 | 21.7 | 45.4 |

(b) The preconditioning capacity of Pack 123A at 40° C was 27.9 ampere-hours. An equipment failure interrupted the first capacity check. The pack was then allowed to complete an additional month of cycling in order to let the cells stabilize again before receiving a capacity check, but the pack failed shortly before the capacity check was to have begun.

10. General Electric 5.0 ah (NIMBUS), Six 5-cell Packs, 1.5-hour Orbit Period:

a. Cell Description: These cells are cylindrical in shape with a convex base. A threaded stud is fastened to the base to facilitate heat sink mounting. The cell container and the cell cover are made of stainless steel. Two stainless steel tabs, welded to the cover, serve as the contacts for the negative terminal. The positive terminal is insulated from the cell cover by a ceramic bushing and protrudes through the bushing with a solder tab welded to the terminal. Three cells have pressure transducers mounted on the cell to read internal pressure in pounds per square inch absolute. These cells were designed for use in the NIMBUS satellite.

b. Test Parameters:

| Pack Number | Test Temperature | Percent Depth of Discharge | Percent of Recharge | Charge Voltage Limit, Per Cell |
|---|---|---|---|---|
| 103A | 0° C | 15 | 110 | 1.49 ± 0.03 |
| 107A* | 0° C | 25 | 110 | 1.49 ± 0.03 |
| 106A | 25° C | 15 | 120 | 1.49 ± 0.03 |
| 104B* | 25° C | 25 | 120 | 1.49 ± 0.03 |
| 113A | 40° C | 15 | 130 | 1.49 ± 0.03 |
| 114A* | 40° C | 25 | 130 | 1.49 ± 0.03 |

* One cell in these packs is equipped with a pressure transducer.

c. Test Results:

(1) Performance on cycling: (Figures 24(A) through 24(D).) Cycling was started in May 1965. These packs have completed from 4998 to 14,883 cycles with 11 cell failures. The main cause of the first nine failures was the shorting of the positive tab to the negative plate. In one case this condition was so severe that the cells overheated and went into thermal runaway destroying the entire pack (Pack 113A). Separator deterioration and migration was present in the last two cell failures.

(2) Capacity checks: The ampere-hour capacities on the preconditioning and capacity check cycles are as follows:

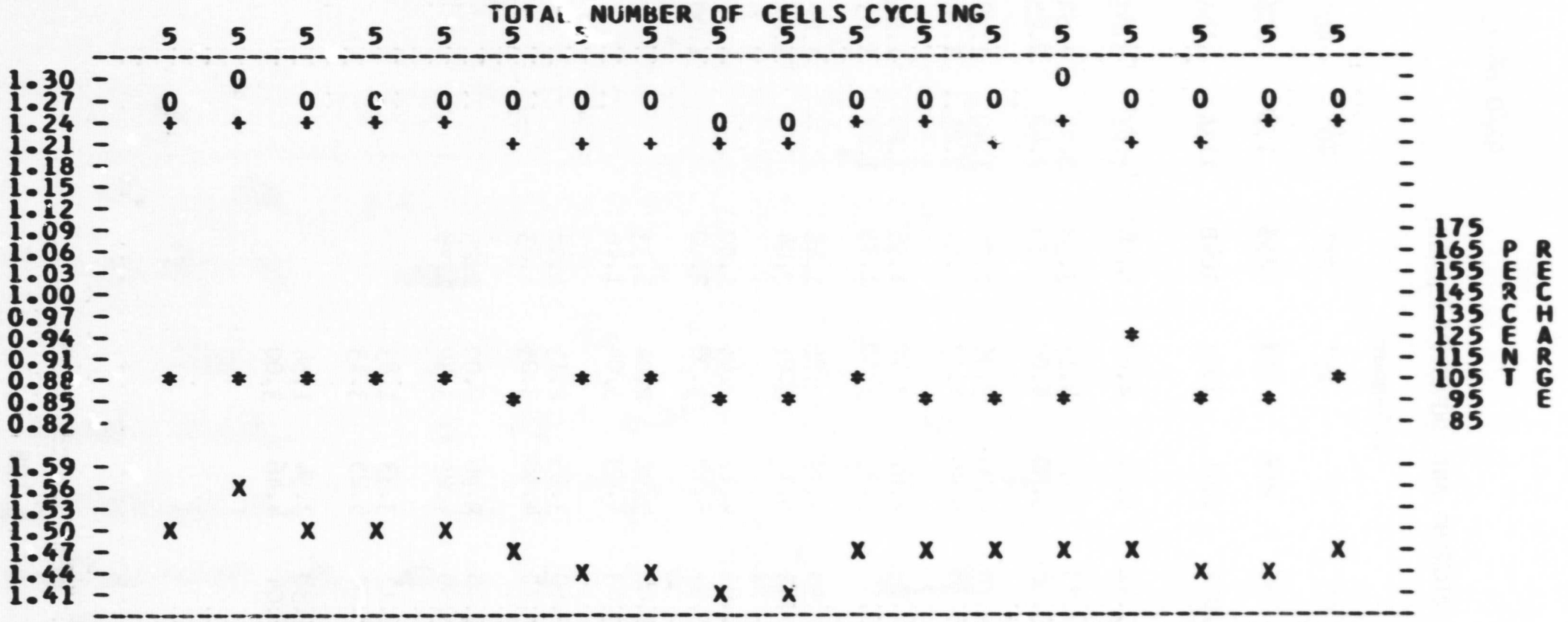
## PRECONDITIONING AND CAPACITY CHECKS

| Orbit Period | | 1.5-hour | | | | | |
|---|---|---|---|---|---|---|---|
| Temperature | | 0° | 0° | 25° | 25° | 40° | 40° |
| Depth of Discharge | | 15% | 25% | 15% | 25% | 15% | 25% |
| Pack Number | | 103A | 107A | 106A | 104B | 113A | 114A |
| Preconditioning Capacity | | 5.42 | 5.21 | 4.67 | 5.58 | 3.67 | 3.83 |
| 88 Days | Disch #1 | 4.75 | 5.00 | 4.13 | 3.38 | 2.33 | 1.67 |
| | Disch #2 | 5.08 | 5.50 | 4.00 | 3.58 | 2.42 | 2.25 |
| 176 Days | Disch #1 | 4.70 | 4.96 | 3.96 | 2.25 | 1.40 | 1.38 |
| | Disch #2 | 5.38 | 5.46 | 4.13 | 2.54 | 2.25 | 1.71 |
| 264 Days | Disch #1 | 4.79 | 4.67 | 3.42 | 1.58 | 1.29 | 1.21 |
| | Disch #2 | 5.58 | 5.33 | 3.50 | 1.75 | 1.83 * | 1.63 |
| 352 Days | Disch #1 | 4.58 | 4.79 | 2.88 | 1.46 | | 1.42 |
| | Disch #2 | 5.42 | 5.17 | 3.21 | 2.04 | | 1.21 |
| 440 Days | Disch #1 | 4.63 | 4.17 | 2.46 | 1.50 | | 1.08 |
| | Disch #2 | 5.54 | 5.42 | 3.08 | 2.00 | | 1.00 * |
| 528 Days | Disch #1 | 4.08 | 3.92 | 2.04 | 1.33 | | |
| | Disch #2 | 5.13 | 4.83 | 3.04 | 1.46 | | |
| 616 Days | Disch #1 | 2.50 | 3.25 | 2.13 | 1.38 | | |
| | Disch #2 | 4.75 | 4.58 | 3.25 | 1.83 | | |
| 704 Days | Disch #1 | 4.46 | 2.96 | 2.00 | 1.25 | | |
| | Disch #2 | 5.00 | 4.25 | 3.42 | 1.38 * | | |
| 792 Days | Disch #1 | 4.17 | 3.33 | 1.83 | | | |
| | Disch #2 | 5.08 | 5.25 | 3.13 | | | |
| 880 Days | Disch #1 | 4.38 | 3.54 | 1.54 | | | |
| | Disch #2 | 5.04 | 4.46 | 3.00 | | | |

* Pack Failed

KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE

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POS. NO. CYCLE FAILED

PACK NUMBER 103A
TYPE OF CELLS GE 5.00 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 15 PERCENT
SPECIFIED CHARGE RATE 0.83 AMP.

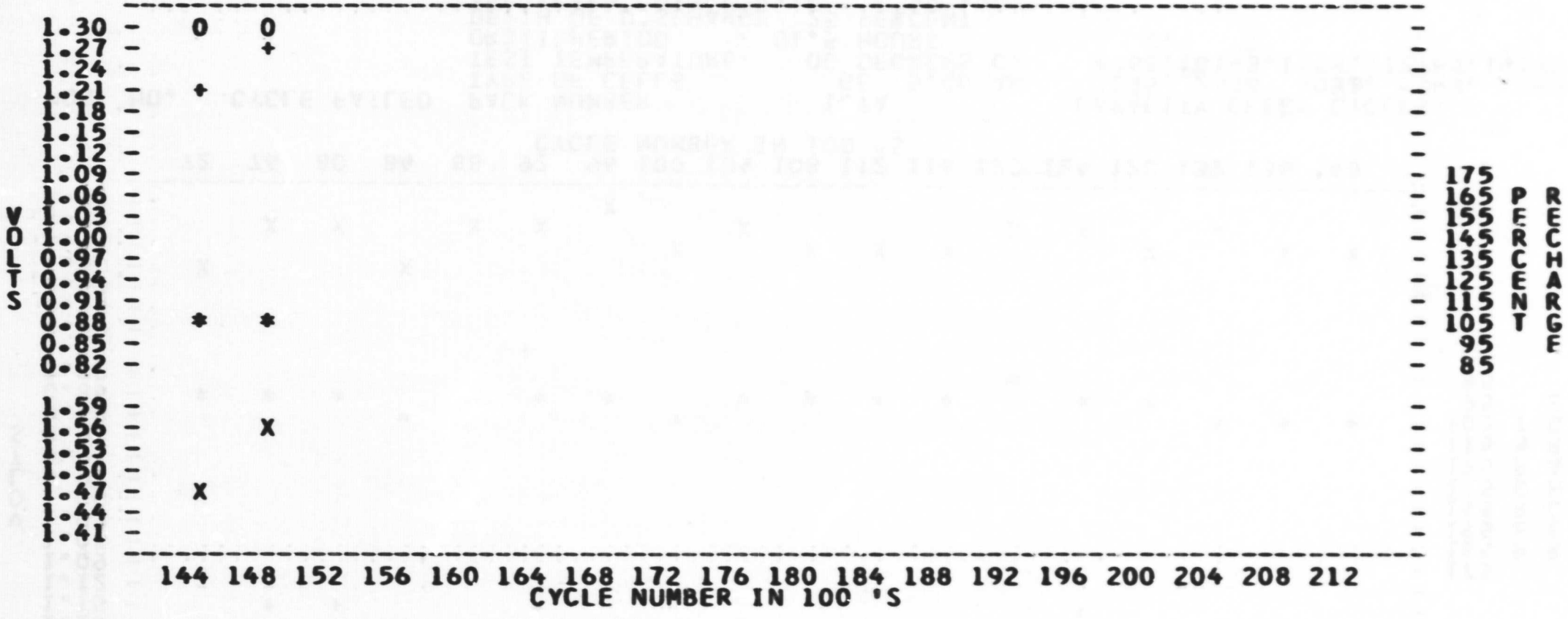
STATUS CELLS CYCLING 5
CYCLES COMPLETED 14883

CAPACITY CHECK CYCLES
1846, 2987, 4582, 6194, 7543
9419,10794,12232,13387,14795
0,

FIGURE 24(A)

KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE

QE/C 68-138




POS. NO. CYCLE FAILED

PACK NUMBER 103A
TYPE OF CELLS GE 5.00 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 15 PERCENT
SPECIFIED CHARGE RATE 0.83 AMP.

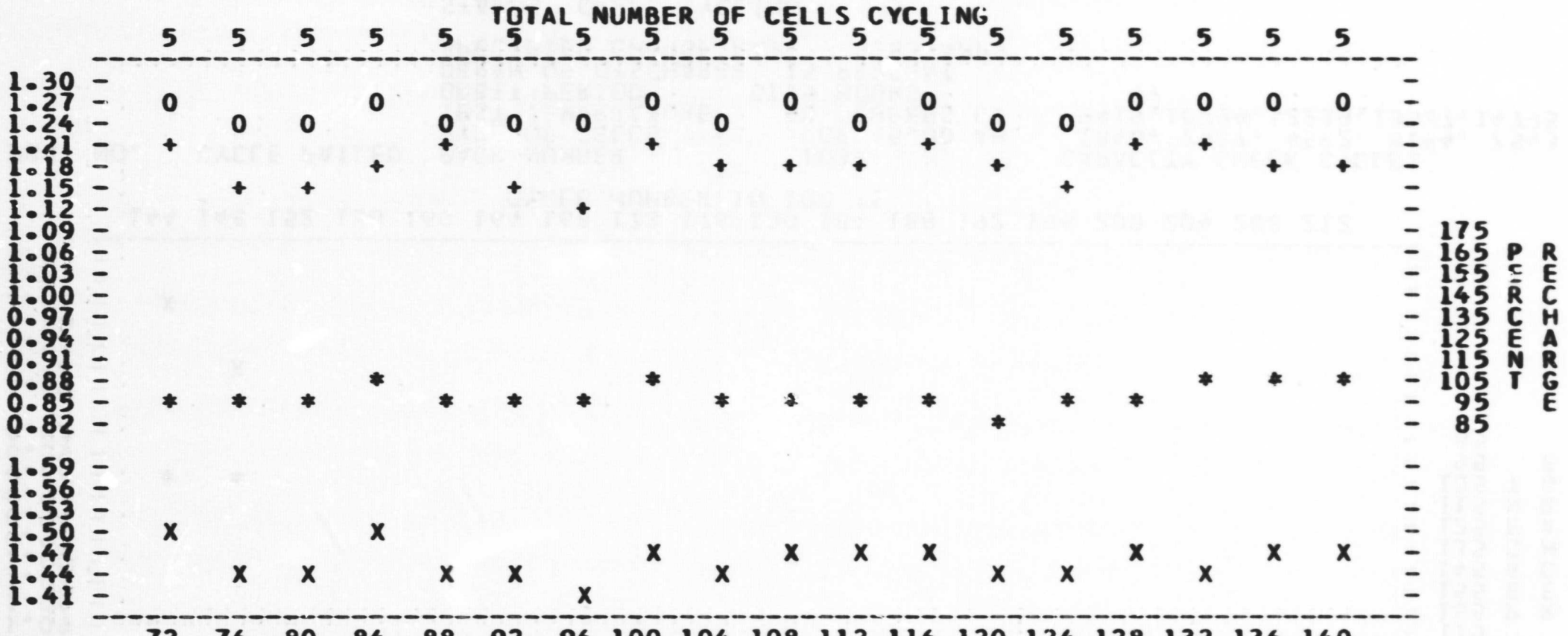
STATUS CELLS CYCLING 5
CYCLES COMPLETED 14883

CAPACITY CHECK CYCLES
1846, 2987, 582, 6194, 7543
9419,10794,12232,13387,14795
0,

FIGURE 24(A) (CONTD)

KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE

QE/C 68-138




POS. NO. CYCLE FAILED

PACK NUMBER 107A
TYPE OF CELLS GE 5.00 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 1.38 AMP.

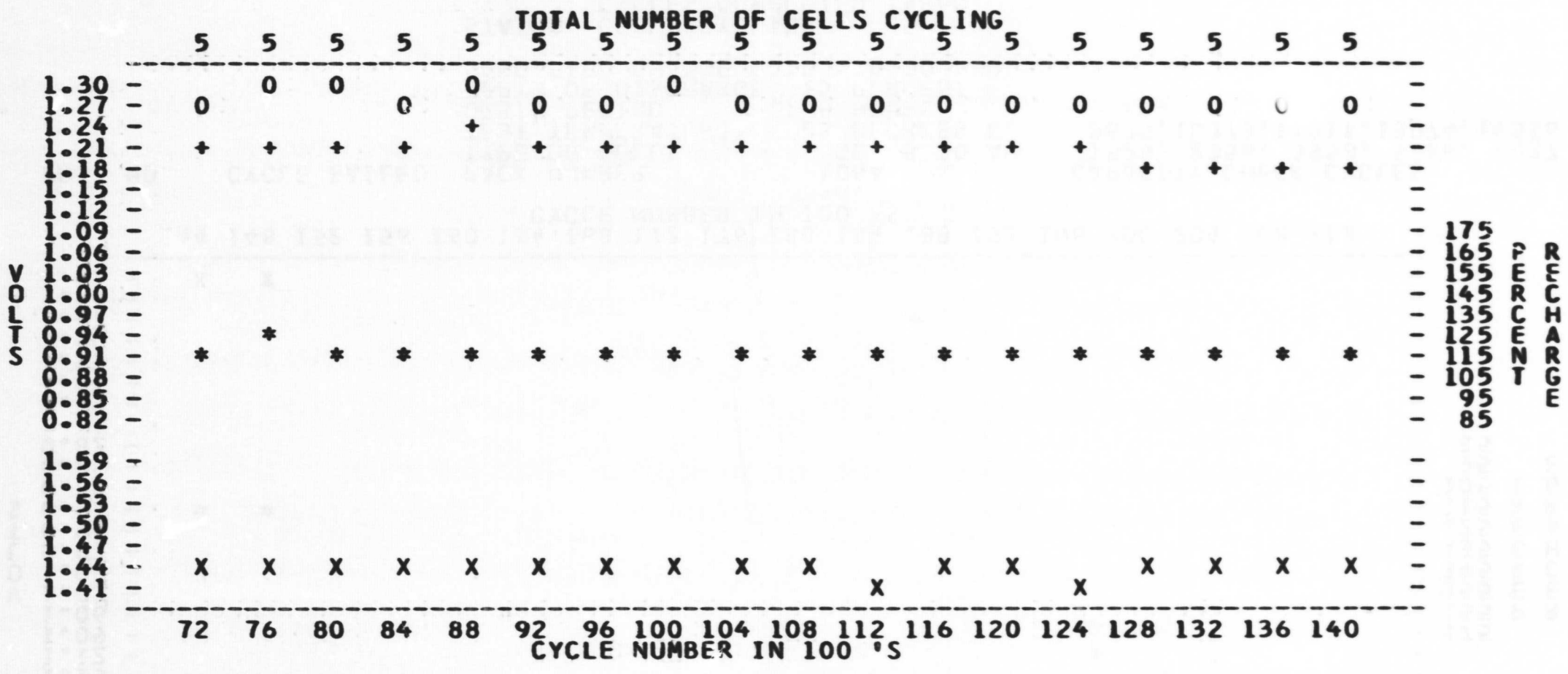
STATUS CELLS CYCLING 5
CYCLES COMPLETED 14229

CAPACITY CHECK CYCLES
1195, 2336, 3931, 5543, 6892
8768,10143,11581,12765,14170
0,

FIGURE 24(B)

KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE

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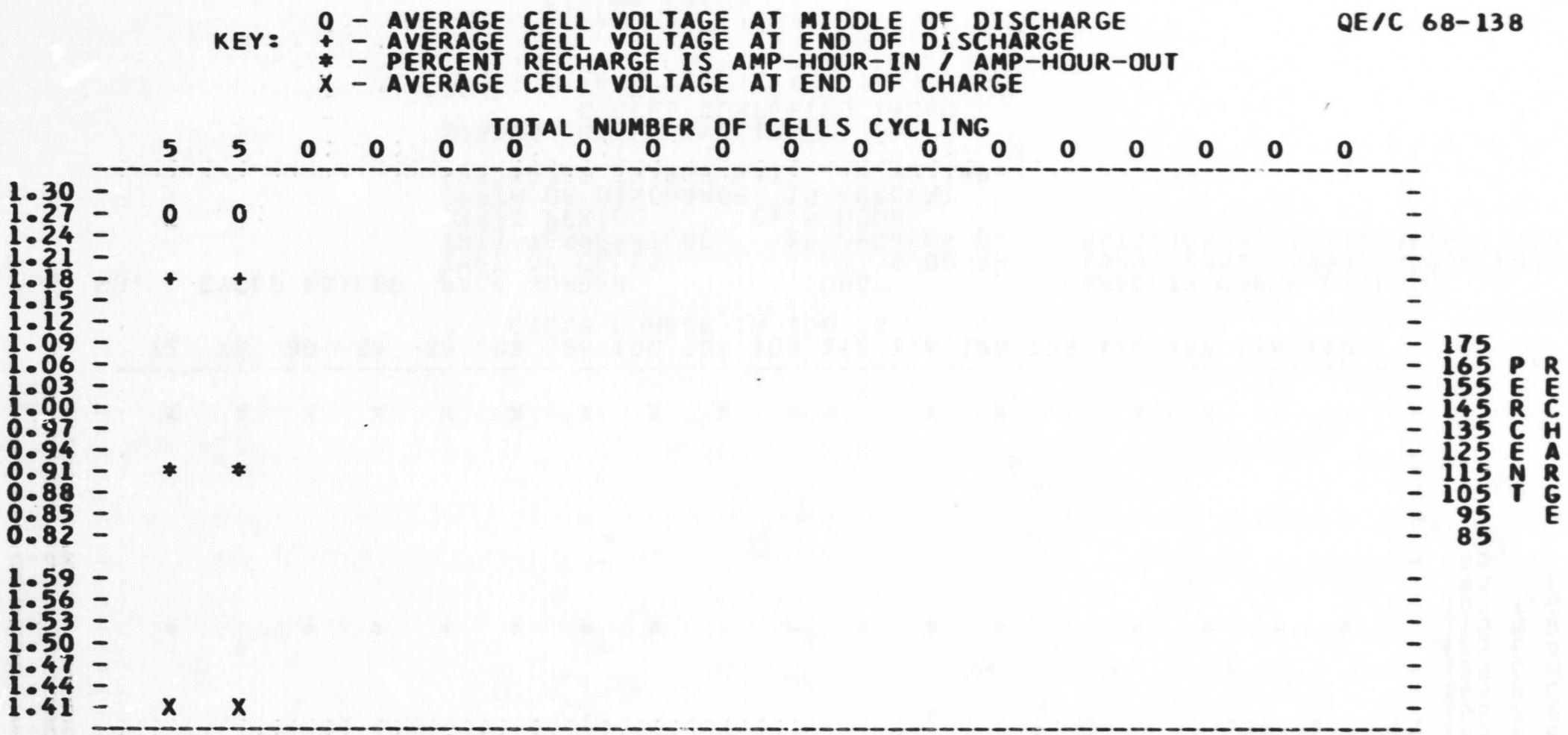

POS. NO. CYCLE FAILED

PACK NUMBER 106A
TYPE OF CELLS GE 5.00 AH
TEST TEMPERATURE 25 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 15 PERCENT
SPECIFIED CHARGE RATE 0.90 AMP.

STATUS CELLS CYCLING 5
CYCLES COMPLETED 14860

CAPACITY CHECK CYCLES
1529, 2356, 3958, 5588, 7027
8675,10373,11811,13074,14516
0,

FIGURE 24(C)




POS. NO. CYCLE FAILED

PACK NUMBER 106A
TYPE OF CELLS GE 5.00 AH
TEST TEMPERATURE 25 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 15 PERCENT
SPECIFIED CHARGE RATE 0.90 AMP.

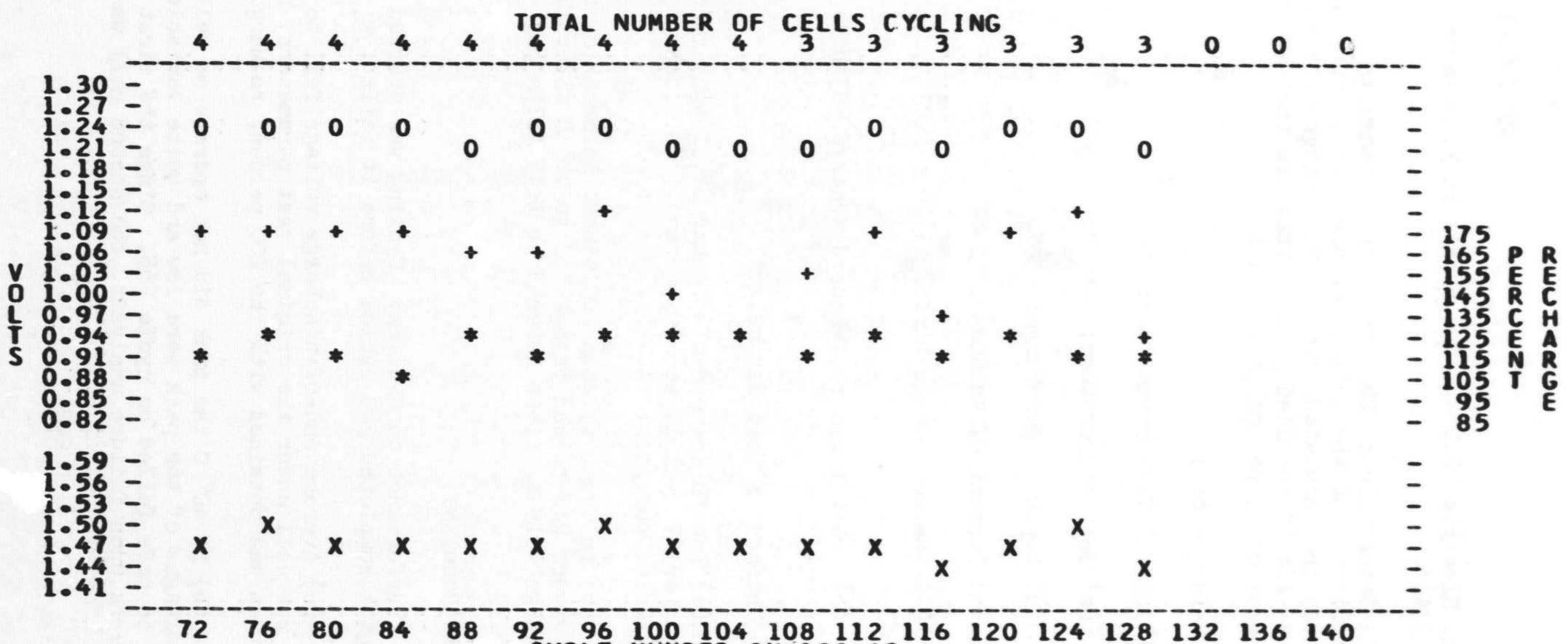
STATUS CELLS CYCLING 5
CYCLES COMPLETED 14860

CAPACITY CHECK CYCLES
1529, 2356, 3958, 5588, 7027
8675,10373,11811,13074,14516
0,

FIGURE 24(C) (CONTD)

KEY: 0 – AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ – AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* – PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X – AVERAGE CELL VOLTAGE AT END OF CHARGE

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| POS. NO. | CYCLE FAILED |
|---|---|
| 04 | 5164 |
| 03 | 10463 |
| 01 | 13149 |

PACK NUMBER 104B
TYPE OF CELLS GE 5.00 AH
TEST TEMPERATURE 25 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 1.50 AMP.

CAPACITY CHECK CYCLES
1657, 3259, 4889, 6311, 7959
9660,10575,11838,

STATUS PACK FAILED
ON CYCLE NUMBER 13149

CYCLES 15-510: POS. 4 REMOVED FROM AUTOMATIC CYCLING TO REPAIR PRESSURE TRANSDUCER.

FIGURE 24(D)

11. General Electric 12.0 ah, One 5-cell Pack, 24-hour Orbit Period (Pack 93A):

a. Cell Description: The cells are rectangular in shape. The cell container and the cell cover are made of stainless steel. Both terminals are insulated from the cell cover by ceramic seals and protrude as 1/4-20 threaded posts. They are the same as those described in section I, paragraph II.A.1.b.

b. Test Parameters:

(1) Initial Test Parameters:

(a) Test Temperature: 25° C.

(b) Depth of Discharge: 50%.

(c) Percent of Recharge: 150%

(d) Charge Voltage Limit: 1.49 ± 0.03 volts per cell, average.

(e) Orbit Period: 1-hour discharge, 23-hour charge.

(2) Changes in Test Parameters:

(a) Due to low end-of-discharge voltage, recharging was increased, after 57 cycles, to 200 percent. This change improved the operation of the pack.

(b) In order to gain additional information the environmental temperature was raised from 25° C to 40° C after 173 cycles, with the charge voltage limit lowered to 1.45 volts per cell, average.

c. Test Results:

(1) Performance on cycling: Cycling was started in March 1964. This pack completed 349 cycles before it failed.

(a) Average end-of-discharge voltage fell to less than 1.0 volt per cell under the original test parameters, but satisfactory operation was obtained with the 200 percent recharge.

(b) At 40° C the pack did not operate as well. End-of-discharge voltages of the pack were low and quite variable. Two cells appeared to have failed on cycle 266. Since the first cell showed no defects upon failure analysis, the second cell was

discharged completely and shorted overnight. It was then charged for 16 hours at the c/10 rate, and finally discharged again at the c/2 rate, all at 25° C. Its capacity was thus found to be 12.9 ampere-hours. It was returned to the pack and continued to cycle until the pack failed on cycle 349. The cycling behavoir of these two cells was attributed to a combination of memory effect and insufficient percent of recharge. At no time was the on charge voltage limit reached. The end-of-charge voltage remained close to 1.39 volts per cell at both temperatures.

(c) The four remaining cells failed on cycle 349. All of the cells showed separator deterioration and migration of the negative plate material. All cells showed signs of leakage around the terminals but no weight loss was detected.

(2) Capacity checks: The ampere-hour capacities on the preconditioning and capacity check cycles are as follows:

| | 100 Days | | 231 Days | | 339 Days | |
|---|---|---|---|---|---|---|
| | Discharge | | Discharge | | Discharge | |
| Preconditioning | at 25° C | | at 40° C | | at 40° C | |
| at 25° C | #1 | #2 | #1 | #2 | #1 | #2 |
| 13.0 | 6.55 | 7.60 | 5.20 | 6.50 | 5.00 | 5.00 |

12. Sonotone 3.0 ah (Triple Seal), Six 5-cell Packs, 1.5-hour Orbit Period:

a. Cell Description: The cell container and the cell cover of these cylindrical cells are made of stainless steel. Two stainless steel tabs, welded to the cover, serve as the contacts for the negative terminal. The positive terminal is a solder type extension of the positive plate tab extending through the "negative" cover and insulated by a ceramic seal between two glass to metal seals to form a triple seal. Two ring indentations, about 1/32 inch deep, located about 1/2 inch from each end of the cell, were crimped after cell assembly to hold the element snugly in the cylindrical can to withstand vibration.

b. Test Parameters:

| Pack Number | Test Temperature | Depth of Discharge | Percent of Recharge | Charge Voltage Limit, Per Cell |
|---|---|---|---|---|
| 43B | 0° C | 15 | 115 | 1.55 ± 0.03 |
| 31B | 0° C | 25 | 115 | 1.55 ± 0.03 |
| 3B | 25° C | 25 | 125 | 1.49 ± 0.03 |
| 2B | 25° C | 40 | 125 | 1.49 ± 0.03 |
| 26B | 40° C | 15 | 160 | 1.45 ± 0.03 |
| 37B | 40° C | 25 | 160 | 1.45 ± 0.03 |

c. Test Results:

(1) Performance on cycling: (Figures 25(A) through 25(C).) Cycling was started in July 1965. These packs have completed from 5399 to 13,430 cycles with 13 cell failures. Weak welds, migration of negative plate material, and separator deterioration were the conditions found in the majority of the failed cells. Only three cells showed signs of leakage; two around the seal and one around the fill tube.

(2) Capacity checks: The ampere-hour capacities on the preconditioning and capacity check cycles are as follows:

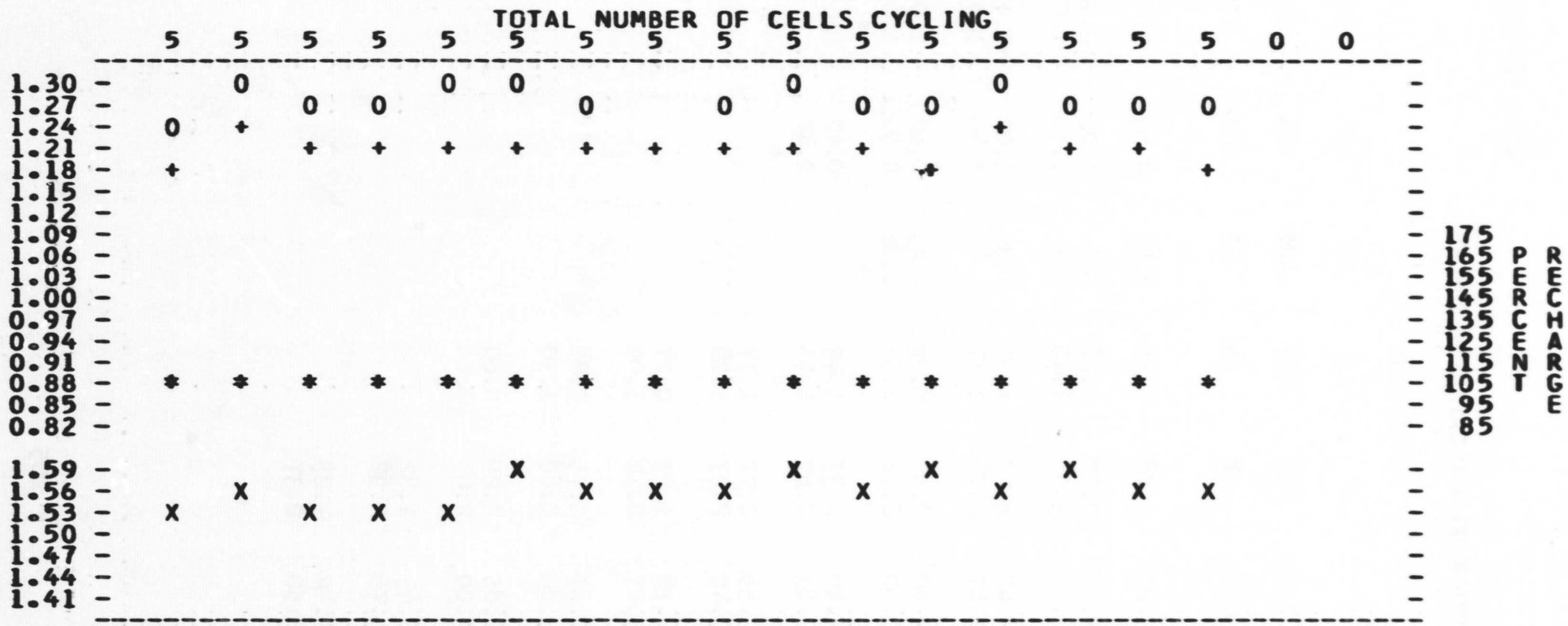
## PRECONDITIONING AND CAPACITY CHECKS

| Orbit Period | | 1.5-hour | | | | | |
|---|---|---|---|---|---|---|---|
| Temperature | | 0° | 0° | 25° | 25° | 40° | 40° |
| Depth of Discharge | | 15% | 25% | 25% | 40% | 15% | 25% |
| Pack Number | | 43B | 31B | 3B | 2B | 26B | 37B |
| Preconditioning Capacity | | 3.23 | 2.88 | 3.35 | 3.60 | 3.53 | 3.48 |
| 88 Days | Disch #1 | 3.35 | 2.72 | 1.28 | 0.50 | 1.02 | 0.90 |
| | Disch #2 | 3.55 | 3.05 | 1.40 | 1.32 | 1.10 | 1.05 |
| 176 Days | Disch #1 | 3.42 | 2.65 | 1.07 | 1.32 | 1.02 | 0.95 |
| | Disch #2 | 3.47 | 2.78 | 1.17 | 1.45 | 1.40 | 1.05 |
| 264 Days | Disch #1 | 3.40 | 2.57 | 0.92 | 1.45 | 0.62 | 1.00 |
| | Disch #2 | 3.50 | 2.72 | 1.50 | 1.62 * | 0.90 | 1.05 * |
| 352 Days | Disch #1 | 3.40 | 2.37 | 1.43 | | 0.42 | |
| | Disch #2 | 2.63 | 2.67 | 1.45 | | 0.47 * | |
| 440 Days | Disch #1 | 3.35 | 0.77 | 1.17 | | | |
| | Disch #2 | 3.42 | 2.27 | 1.28 | | | |
| 528 Days | Disch #1 | 2.78 | 1.25 | 0.77 | | | |
| | Disch #2 | 3.27 | 2.12 | 1.00 | | | |
| 616 Days | Disch #1 | 2.67 | 1.75 | 0.85 | | | |
| | Disch #2 | 3.00 | 2.60 | 1.30 | | | |
| 704 Days | Disch #1 | 2.85 | 2.25 | 0.60 | | | |
| | Disch #2 | 3.00 | 2.67 | 0.40 * | | | |
| 880 Days | Disch #1 | 2.63 | 1.82 | | | | |
| | Disch #2 | 2.75 | 2.52 | | | | |
| 968 Days | Disch #1 | 2.42 | 1.25 | | | | |
| | Disch #2 | 2.50 | 2.37 | | | | |

* Pack Failed

KEY: Q - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE

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POS. NO. CYCLE FAILED

PACK NUMBER 043B
TYPE OF CELLS SONOTONE 3.00 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 15 PERCENT
SPECIFIED CHARGE RATE 0.52 AMP.

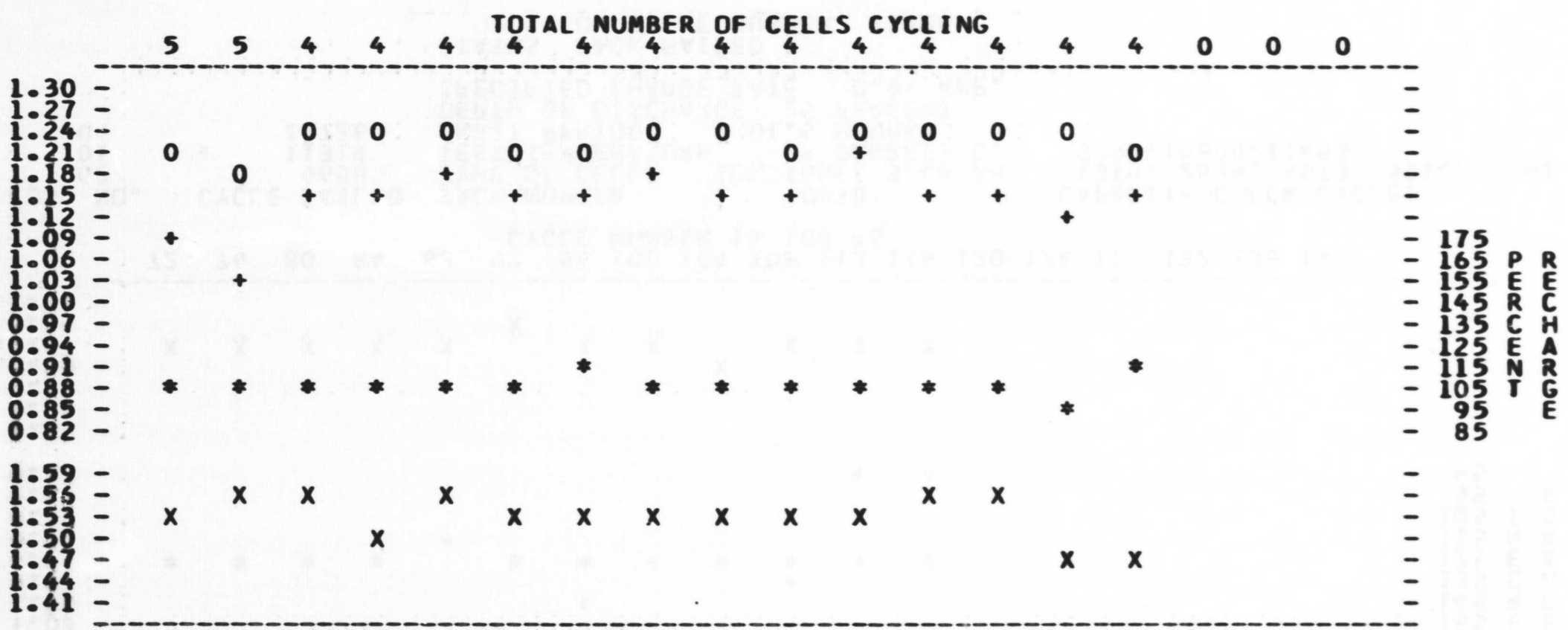
STATUS CELLS CYCLING 5
CYCLES COMPLETED 13430

CAPACITY CHECK CYCLES
1274, 2430, 2780, 4413, 5689
7311, 8864,10270,11534,12974
0,

FIGURE 25(A)

KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE

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POS. NO. 05

CYCLE FAILED 7636

PACK NUMBER 0318
TYPE OF CELLS SONOTONE 3.00 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 0.86 AMP.

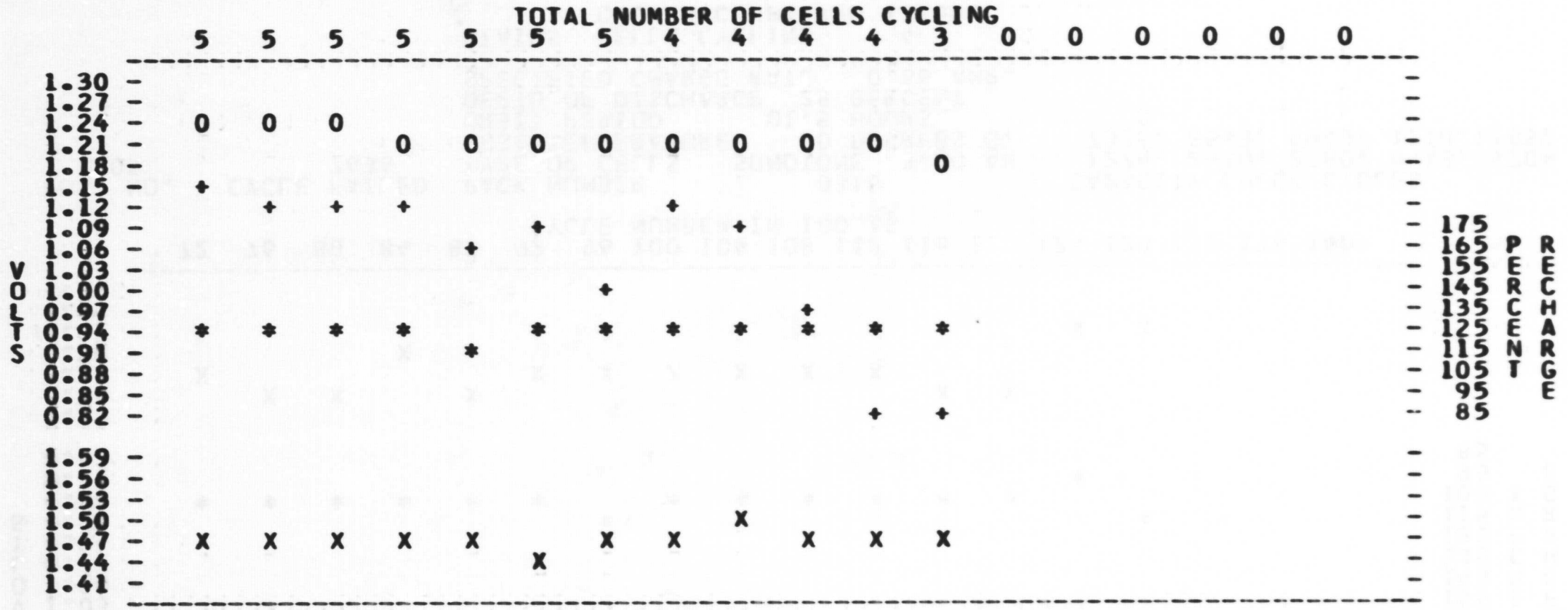
STATUS CELLS CYCLING 4
CYCLES COMPLETED 13108

CAPACITY CHECK CYCLES
1274, 2430, 2780, 4413, 5704
7326, 8543, 9949, 11210, 12652
0,

FIGURE 25(B)

KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE

QE/C 68-138




| POS. NO. | CYCLE FAILED |
|---|---|
| 02 | 9658 |
| 01 | 11319 |
| 04 | 11726 |

PACK NUMBER 003B
TYPE OF CELLS SONOTONE 3.00 AH
TEST TEMPERATURE 25 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 0.94 AMP.

STATUS PACK FAILED
ON CYCLE NUMBER 11726

CAPACITY CHECK CYCLES
1310, 2834, 4573, 5910, 7641
9295,10609,11653,

FIGURE 25(C)

13. Sonotone 3.5 ah, One 10-cell Pack, 1.5-hour Orbit Period (Pack 15B):

a. Cell Description: These are cylindrical cells made of stainless steel. One stainless steel tab is welded to the cover for the negative connection. The positive terminal is an extension of the positive tab and is insulated from the negative cover by a ceramic seal. Two ring indentations, about 1/32 inch deep, located approximately 1/2 inch from either end of the cell can, were crimped after cell assembly to hold the element snugly in the cylindrical can.

b. Test Parameters:

(1) Initial Test Parameters (at previous test facility):

(a) Test Temperature: -10° C.

(b) Depth of Discharge: 10%.

(c) Percent of Recharge: 110%.

(d) Cnarge Voltage Limit: 1.55 ± 0.03 volts per cell, average.

(e) Orbit Period: 30-minute discharge, 1-hour charge.

(2) Change in Test Parameters: The test temperature was raised to 0° C after 22,900 cycles at -10° C at another test facility.

c. Test Results:

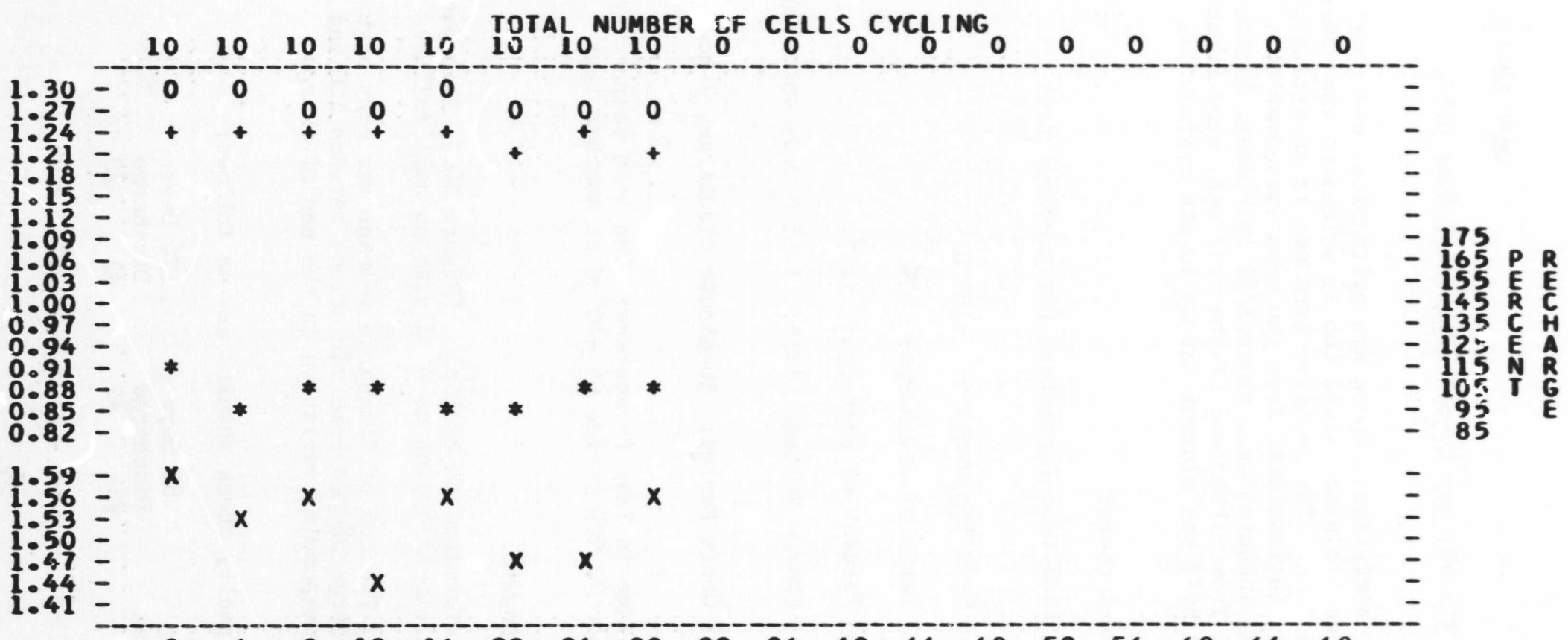
(1) Performance on cycling: (Figure 26.) This pack has completed 2999 additional cycles at 0° C with no cell failures.

(a) The end of discharge voltage was very high but the percent of recharge showed some variations between 100 and 105 percent with a corresponding variation in the end of charge voltage.

(2) Capacity check results are as follows:

| Precon-ditioning | 88 Days Discharge | | 176 Days Discharge | |
|---|---|---|---|---|
| | #1 | #2 | #1 | #2 |
| 3.18 | 2.68 | 3.09 | 2.57 | 2.86 |

KEY: 0 – AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ – AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* – PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X – AVERAGE CELL VOLTAGE AT END OF CHARGE




POS. NO. CYCLE FAILED

PACK NUMBER 015B
TYPE OF CELLS SONOTONE 3.50 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 10 PERCENT
SPECIFIED CHARGE RATE 0.39 AMP.

CAPACITY CHECK CYCLES
1440, 2767,

STATUS CELLS CYCLING 10
CYCLES COMPLETED 2999

THIS PACK HAD RECIEVED 22900 CYCLES AT 10 PERCENT DEPTH OF DISCHRGE AT -10 DEGREES CENTIGRADE BEFORE STARTING CYCLE 1 AT N.A.D. CRANE.

FIGURE 26

14. NIFE 3.9 ah, Two 5-cell Packs, 1.5-hour Orbit Period:

a. Cell Description: The cell container and the cell cover of these cylindrical cells are made of stainless steel. The cell container serves as the negative terminal. The positive terminal is a button extension of the positive plate tab through the center of the cover. The positive terminal is isolated from the negative container by means of a membrane seal. Connections are made by soldering directly to the container and the positive terminal.

b. Test Parameters:

| Pack Number | Test Temperature | Percent Depth of Discharge | Percent of Recharge | Charge Voltage Limit, Per Cell |
|---|---|---|---|---|
| 97C | 0° C | 25 | 107 | 1.47 ± 0.03 |
| 85C | 25° C | 25 | 107 | 1.47 ± 0.03 |

c. Test Results:

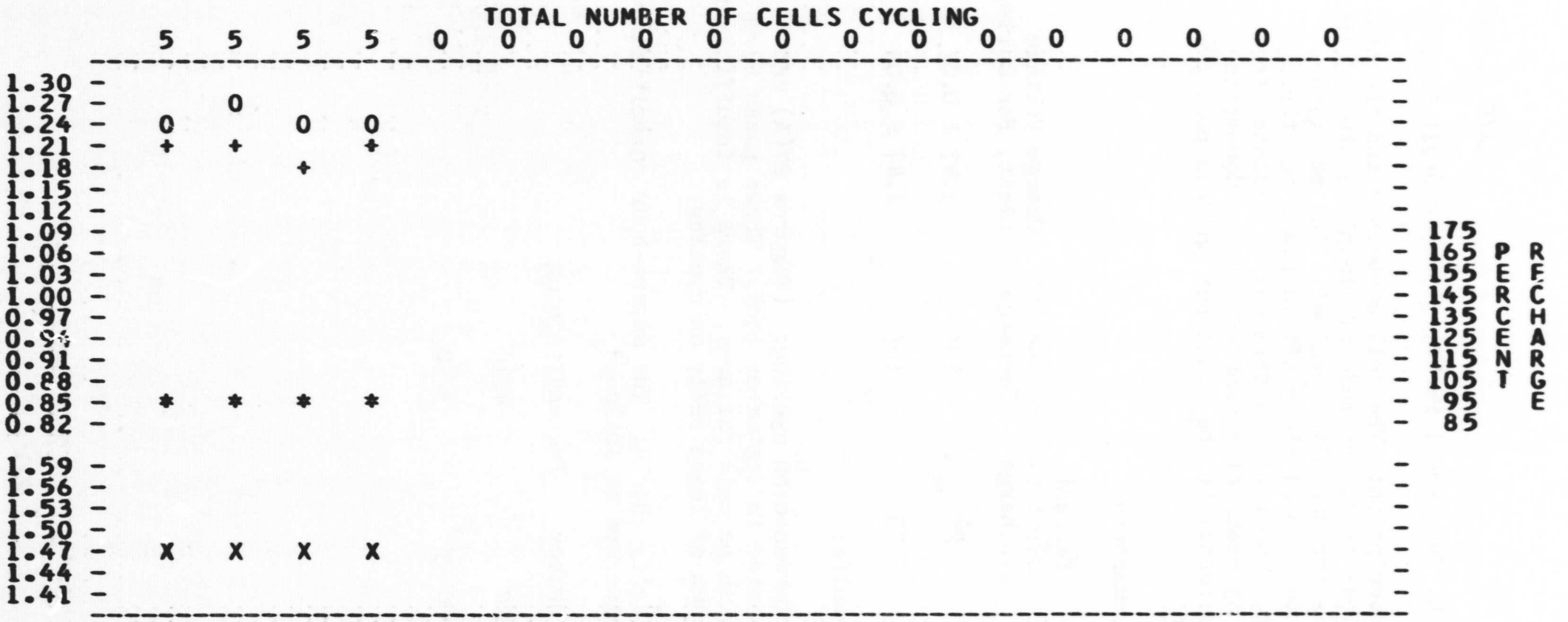
(1) Performance on cycling: (Figures 27(A) and 27(B).) Cycling was started in September 1967. These packs have completed 1274 cycles with no cell failures. There is insufficient data to give an evaluation of these cells on cycling.

(2) Capacity checks: The ampere-hour capacities on the preconditioning cycles are as follows:

| Pack Number | Preconditioning |
|---|---|
| 97C | 4.10 |
| 85C | 3.90 |

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KEY: 0 – AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ – AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* – PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X – AVERAGE CELL VOLTAGE AT END OF CHARGE



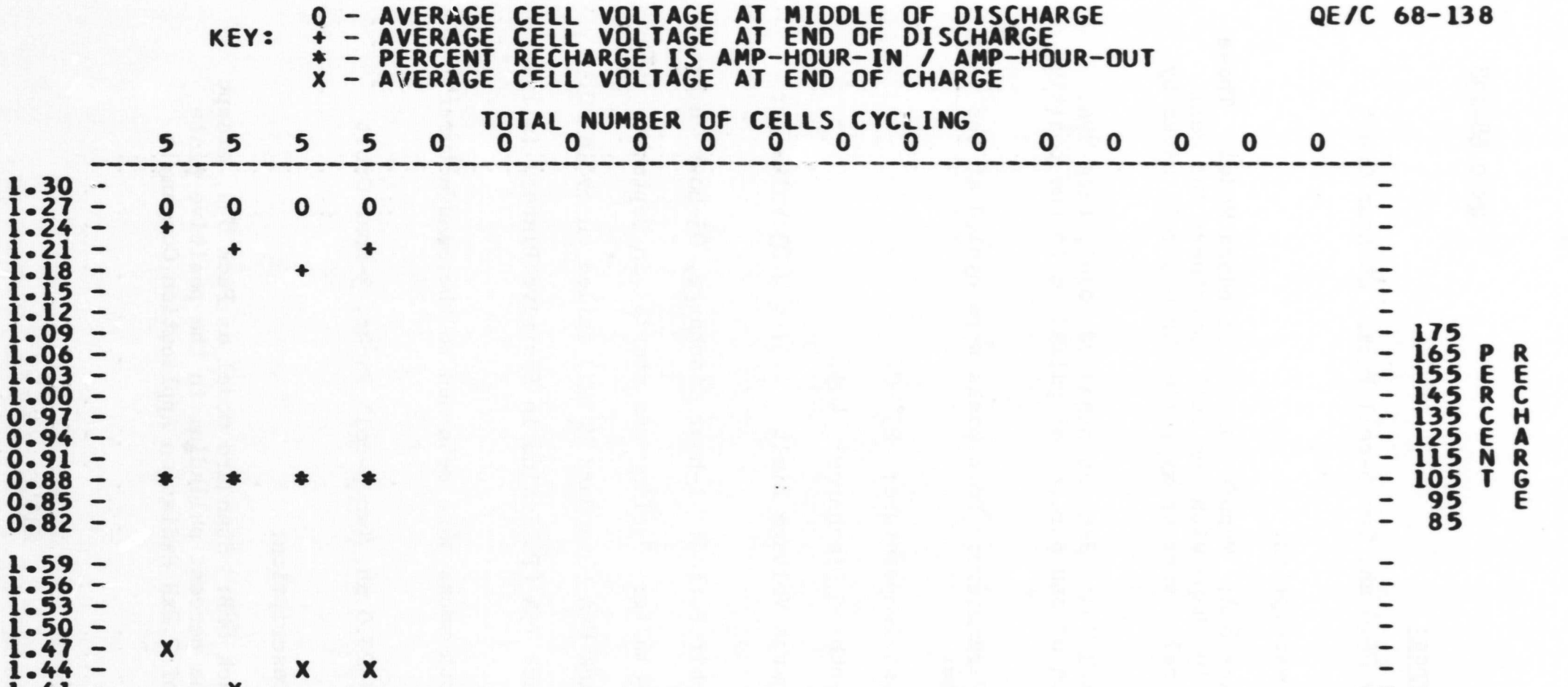

POS. NO. CYCLE FAILED

PACK NUMBER 097C
TYPE OF CELLS NIFE 3.90 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 1.07 AMP.

CAPACITY CHECK CYCLES
0,

STATUS CELLS CYCLING 5
CYCLES COMPLETED 1274

FIGURE 27(A)




POS. NO. CYCLE FAILED

PACK NUMBER 085C
TYPE OF CELLS NIFE 3.90 AH
TEST TEMPERATURE 25 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 1.07 AMP.

CAPACITY CHECK CYCLES
0,

STATUS CELLS CYCLING 5
CYCLES COMPLETED 1274

FIGURE 27(B)

B. Silver-Zinc Types:

1. Delco-Remy 25.0 ah, Two 5-cell Packs, 24-hour Orbit Period:

a. Cell Description:

(1) Pack 89A: Manufacturer's Standard Model. These cells are rectangular in shape with the cell containers and cell covers of nylon. The cells were epoxy potted into 5-cell packs by the manufacturer.

(2) Pack 75A: Same as standard model, Pack 89A, except for the addition of one percent of palladium to the positive plate material.

b. Test Parameters: Both packs were cycled at the test parameters listed below:

(1) Test Temperature: 25° C.

(2) Depth of Discharge: 40%.

(3) Charge Voltage Limit: 1.97 ± 0.03 volts per cell, average.

(4) Orbit Period: 1-hour discharge, 23-hour charge.

c. Test Results: Cycling was started in September 1964.

(1) Pack 89A (Standard Model) failed on cycle 80.

(2) Pack 75A (Palladium in Positive Plates) failed on cycle 32.

(3) Both packs were returned to the manufacturer for failure analysis.

2. Delco-Remy 25.0 ah, Two 5-cell Packs, 3-hour Orbit Period:

a. Cell Description:

(1) Pack 88B: Standard model as Pack 89A, except for the addition of one percent palladium in the positive plate material and the use of 2.2xH Radiation Application Company's separators.

(2) Pack 88C: Standard model as Pack 89A, except for the addition of one percent palladium in the positive plate material, and the use of a 45 percent NaOH solution as the electrolyte.

b. Test Parameters: Both packs were cycled at the test parameters listed below:

(1) Test Temperature: 25° C.

(2) Depth of Discharge: 40%.

(3) Charge Voltage Limit: 1.97 ± 0.03 volts per cell, average.

(4) Orbit Period: 30-minute discharge, 2.5-hour charge.

c. Test Results: Cycling was started in March 1965.

(1) Pack 88B: One cell failed on cycle 100. The remaining cells still functioned on cycle 120; at which time the pack was removed from test.

(2) Pack 88C: Pack 88C failed on cycle 325.

(3) Both packs were returned to the manufacturer for failure analysis.

3. Delco-Remy 40.0 ah, One 5-cell Pack, 24-hour Orbit Period (Pack 75B):

a. Cell Description:

(1) Manufacturer's Standard Model. These cells are rectangular in shape with the cell containers and cell covers of nylon. These cells were epoxy potted into one 5-cell pack by the manufacturer.

b. Test Parameters:

(1) Test Temperature: 25° C.

(2) Depth of Discharge: 40%.

(3) Charge Voltage Limit: 1.97 ± 0.03 volts per cell, average.

(4) Orbit Period: 1-hour discharge, 23-hour charge.

c. Test Results: Cycling was started in October 1964. One cell failed while the pack was being prepared for test; a second cell failed on cycle 34. The remaining three cells still functioned on cycle 139; at which time the pack was removed from test.

4. Yardney 12.0 ah, One 10-cell Pack, 24-hour Orbit Period (Pack 9A):

a. Cell Description:

(1) These are vented cells, rectangular in shape, with the containers and covers of plastic material. They contained a limited amount of electrolyte. The cells were individually epoxy potted to hermetically seal them.

b. Test Parameters:

(1) Test Temperature: 25° C.

(2) Depth of Discharge: 42%.

(3) Charge Voltage Limit: 1.97 ± 0.03 volts per cell, average.

(4) Orbit Period: 1-hour discharge, 23-hour charge.

c. Test Results: Cycling was started in May 1965. One cell failed on cycle 53. Three additional cells failed on cycle 57. Following removal of the failed cells, the remaining cells did not respond to cycling; thus failing the pack.

C. Silver-Cadmium Types:

1. Yardney 3.0 ah (FR-1), One 9-cell Pack, 1.5-hour Orbit Period (Pack 2C):

a. Cell Description: These are vented cells, rectangular in shape, with the cell jars and cell covers molded of a plastic material. The cells were epoxy potted, by the manufacturer, into a metal container like that used in the French satellite, (FR-1).

b. Test Parameters:

(1) Test Temperature: 25° C.

(2) Depth of Discharge: 16.67%.

(3) Charge Voltage Limit: 1.52 ± 0.03 volts per cell, average.

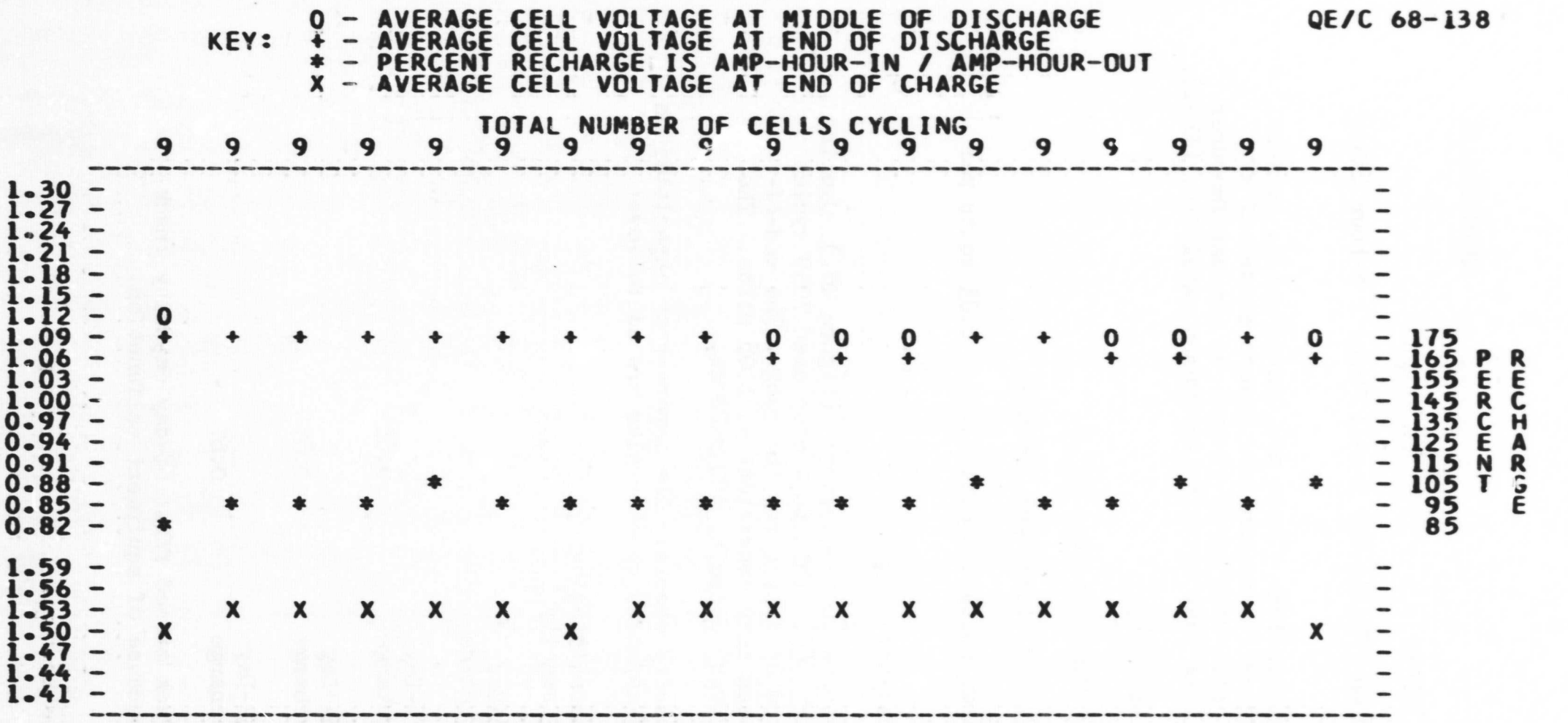
c. Test Results:

(1) Performance on cycling: (Figure 28.) Cycling was started in September 1966. This pack completed 7039 cycles before several cells blew up destroying the pack. The end-of-discharge voltage had been very consistent at 1.08 volts. The percent of recharge was very close to 100 percent.

(2) Capacity checks: The ampere-hour capacities on the preconditioning and capacity check cycles are as follows:

| | |
|---|---|
| Preconditioning Capacity | 2.52 |
| 88-Day Discharge | * |
| 176-Day Discharge | 0.85 |
| 264-Day Discharge | 0.87 |
| 352-Day Discharge | 0.67 |

* Pack missed first 88-day capacity check because of equipment malfunction.




POS. NO. ALL

CYCLE FAILED 7039

PACK NUMBER 002C
TYPE OF CELLS YARDNEY 3.00 AH
TEST TEMPERATURE 25 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 17 PERCENT
SPECIFIED CHARGE RATE 1.30 AMP.

STATUS PACK FAILED
ON CYCLE NUMBER 7039

CAPACITY CHECK CYCLES
3105, 4543, 5869,

FIGURE 28

2. Yardney 5.0 ah (C-3 Separator), Three 5-cell Packs, 24-hour Orbit Period:

a. Cell Description:

(1) These are vented cells, rectangular in shape, with the cell containers and cell covers of plastic material. The plates were insulated with C-3 separators. The cells were epoxy potted into 5-cell packs, at the Goddard Space Flight Center, in order to hermetically seal them.

b. Test Parameters:

| Pack Number | Test Temperature | Percent Depth of Discharge | Charge Voltage Limit, Per Cell |
|---|---|---|---|
| 57B | 0° C | 20 | 1.50 ± 0.03 |
| 21A | 25° C | 20 | 1.50 ± 0.03 |
| 45A | 40° C | 20 | 1.50 ± 0.03 |

c. Test Results: Cycling was started in September 1965. These packs have completed from 61 to 267 cycles will 11 cell failures.

(1) During the cycle life of the packs, the end-of-discharge voltage remained around 1.09 volts whereas the approximate percentage of recharge increased from 105 to 115 percent.

(2) Pack 57B had three cells fail; one on cycle 138 and two on cycle 267. Pack 45A failed on cycle 61 because of severe leakage. Pack 21A had three cells fail; one on cycle 90 and two on cycle 98. The failed packs were returned to Goddard Space Flight Center.

d. Capacity checks: The ampere-hour capacities on the preconditioning and capacity check cycles are as follows:

| Pack Number | Preconditioning | 100 Days | 200 Days |
|---|---|---|---|
| 57B | 3.67 | 1.83 | 1.33* |
| 21A | | 0.76* | |
| 45A | 6.00* | | |

* Pack Failed

3. Yardney 5.0 ah (Cellophane Separator), Two 5-cell Packs, 24-hour Orbit Period:

a. Cell Description: These are vented cells, rectangular in shape, with the cell jars and cell covers molded of a plastic material. The separator material is cellophane (C-19). One of the 5-cell packs (Pack 9C) has been subjected to gama radiation ($2 \times 10^7$ rads). The cells were epoxy potted into 5-cell packs at the Goddard Space Flight Center.

b. Test Parameters:

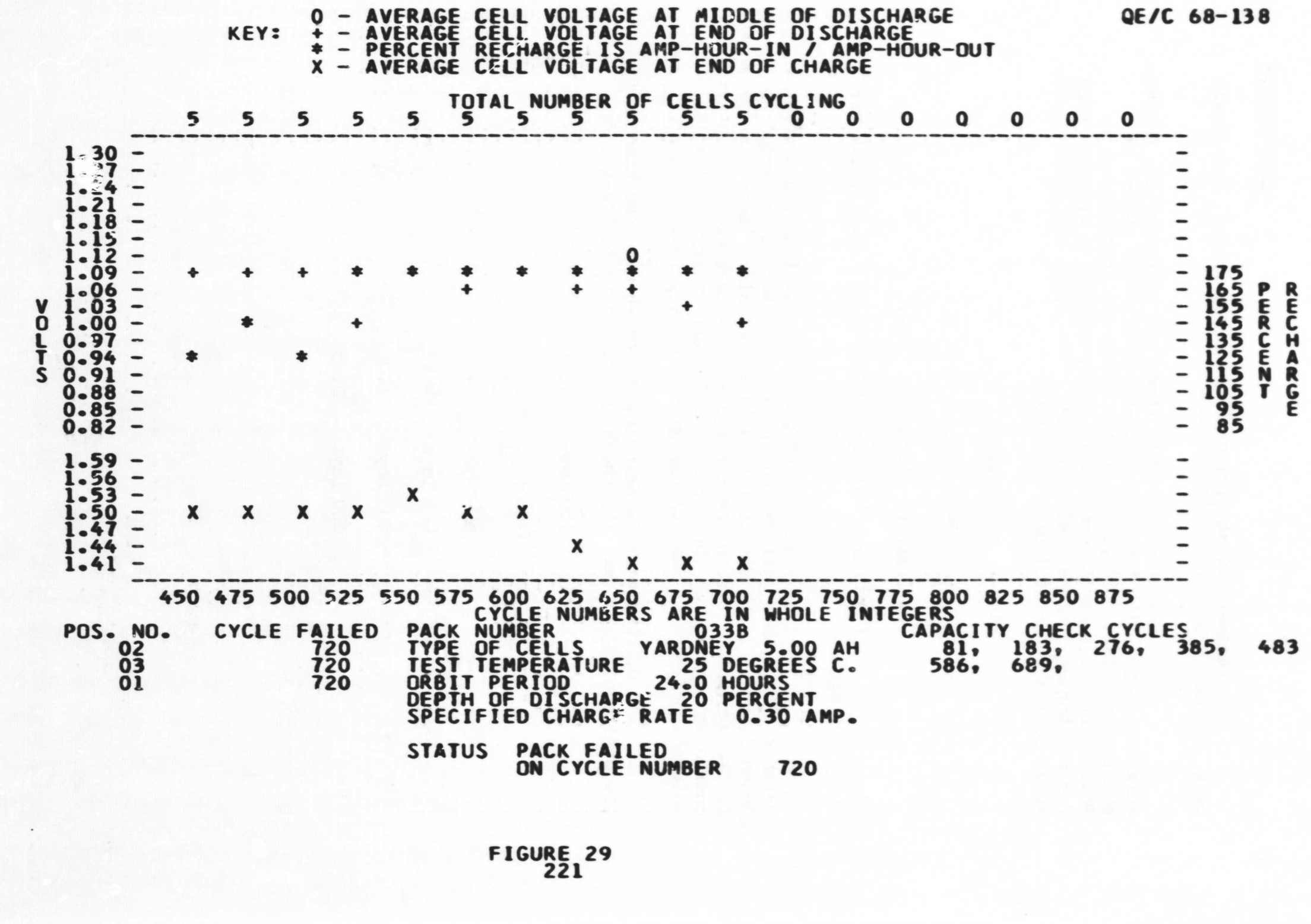
| Pack Number | Test Temperature | Percent Depth of Discharge | Charge Voltage Limit, Per Cell |
|---|---|---|---|
| 9C | 25° C | 20 | 1.50 ± 0.03 |
| 33B* | 25° C | 20 | 1.50 ± 0.03 |

* Control Pack

c. Test Results: (Figure 29.) Cycling was started in October 1965. Pack 9C failed on cycle 34 and was returned to Goddard Space Flight Center. Pack 33B completed 720 cycles with two cell failures. The remaining cells failed while the pack was not cycling. The pack was then returned to Goddard Space Flight Center for failure analysis.

d. Capacity Checks: The ampere-hour capacities of Pack 33B on the preconditioning and capacity check cycles are as follows:

| | |
|---|---|
| 100 Days | 5.85 |
| 200 Days | 6.13 |
| 300 Days | 6.35 |
| 400 Days | 5.48 |
| 500 Days | 2.08 |
| 600 Days | 1.88 |
| 700 Days | 1.00 |




| POS. NO. | CYCLE FAILED |
|---|---|
| 02 | 720 |
| 03 | 720 |
| 01 | 720 |

PACK NUMBER 033B
TYPE OF CELLS YARDNEY 5.00 AH
TEST TEMPERATURE 25 DEGREES C.
ORBIT PERIOD 24.0 HOURS
DEPTH OF DISCHARGE 20 PERCENT
SPECIFIED CHARGE RATE 0.30 AMP.

CAPACITY CHECK CYCLES
81, 183, 276, 385, 483
586, 689,

STATUS PACK FAILED
ON CYCLE NUMBER 720

FIGURE 29

4. Yardney 5.0 ah (Pellon Control Separator), One 5-cell Pack, 24-hour Orbit Period (Pack 69A):

a. Cell Description: These are vented cells, rectangular in shape, with the cell jars and cell covers molded of a plastic material. The plates of the cells are insulated with Pellon control separator material. Each cell has a pressure gage for monitoring internal cell pressure. The cells are individually epoxy potted to hermetically seal them.

b. Test Parameters:

(1) Test Temperature: 25° C.

(2) Depth of Discharge: 20%.

(3) Charge Voltage Limit: 1.50 ± 0.03 volts per cell, average.

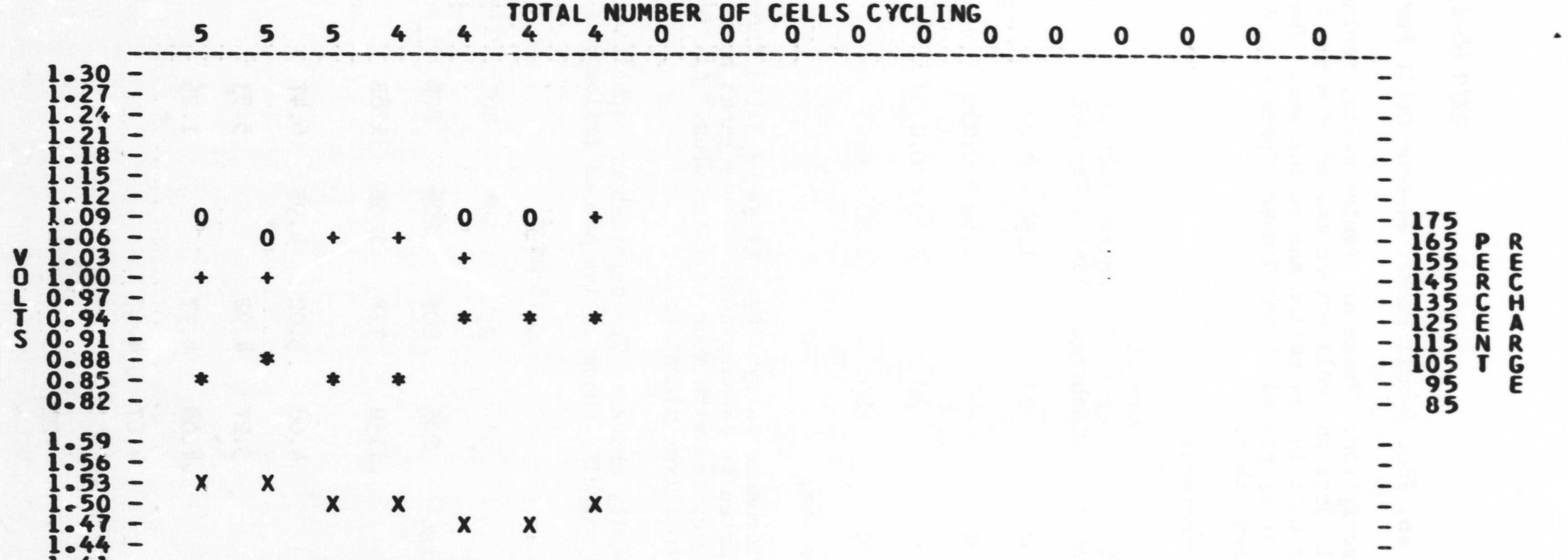
c. Test Results: (Figure 30.) Cycling was started in October 1965. This pack failed on cycle 610 and was returned to Goddard Space Flight Center for failure analysis. There was very little variation in both the average end-of-discharge and end-of-charge voltages until the first cell failure occurred. Also the internal pressure as read on the gages was very low.

d. Capacity Checks: The ampere-hour capacities on the preconditioning and capacity check cycles are as follows:

| | |
|---|---|
| 100 Days | 4.95 |
| 200 Days | 4.17 |
| 300 Days | 3.20 |
| 400 Days | 4.42 |
| 500 Days | 1.02 |
| 600 Days | 2.08 |

KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE

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| POS. NO. | CYCLE FAILED |
|---|---|
| 05 | 494 |
| 04 | 585 |
| 02 | 595 |

PACK NUMBER 069A
TYPE OF CELLS YARDNEY 5.00 AH
TEST TEMPERATURE 25 DEGREES C.
ORBIT PERIOD 24.0 HOURS
DEPTH OF DISCHARGE 20 PERCENT
SPECIFIED CHARGE RATE 0.30 AMP.

CAPACITY CHECK CYCLES
81, 183, 276, 385, 483
585,

STATUS PACK FAILED
ON CYCLE NUMBER 595

FIGURE 30

5. Yardney 5.0 ah, Four 5-cell Packs, 24-hour Orbit Period:

a. Cell Description: These are vented cells, rectangular in shape, with cell jars and cell covers molded of a plastic material. The separator material is pellon and cellophane. The cells were individually epoxy potted at the Goddard Space Flight Center to hermetically seal them.

b. Test Parameters:

| Pack Number | Test Temperature | Percent Depth of Discharge | Charge Voltage Limit, Per Cell |
|---|---|---|---|
| 113B | 0° C | 20 | 1.50 ± 0.03 |
| 77B | 25° C | 20 | 1.50 ± 0.03 |
| 105B | 25° C | 20 | 1.50 ± 0.03 |
| 128B | 40° C | 20 | 1.50 ± 0.03 |

c. Test Results:

(1) Performance on cycling: (Figures 31(A) through 31(D).) Cycling was started in January 1967. These packs have completed from 77 to 339 cycles with four cell failures. All four cell failures were due to silver migration.

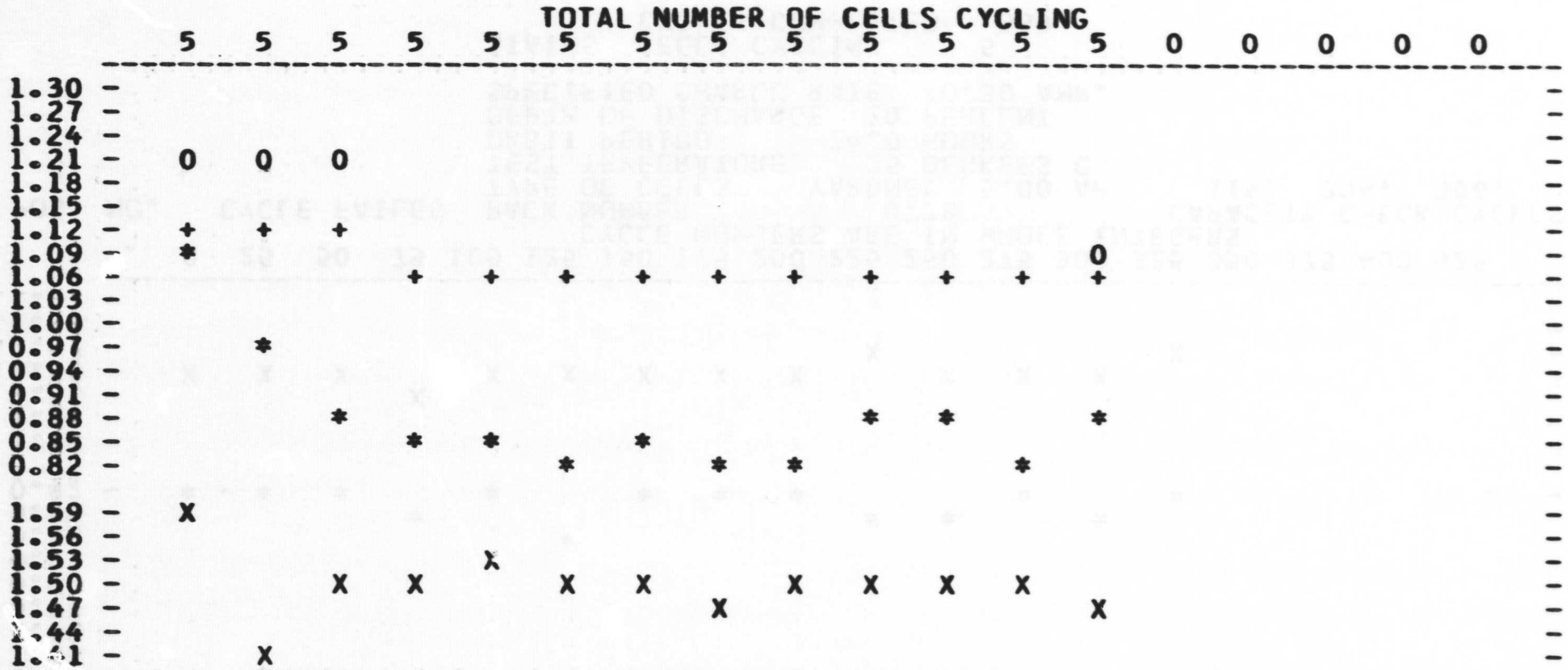
(2) Capacity checks: The ampere-hour capacities on the preconditioning and capacity check cycles are as follows:

| Orbit Period | 1.5-hour | | | |
|---|---|---|---|---|
| Temperature | 0° | 25° | 25° | 40° |
| Depth of Discharge | 20% | 20% | 20% | 20% |
| Pack Number | 113B | 77B | 105B | 128B |
| Preconditioning Capacity | 4.08 | 5.02 | 4.95 * | 6.47 |
| 100 Days | 5.27 | 4.92 | | 5.53 |
| 200 Days | 4.08 | 4.77 | | 1.25 * |
| 300 Days | 4.67 | 4.67 | | |

* Pack Failed

KEY: O - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE

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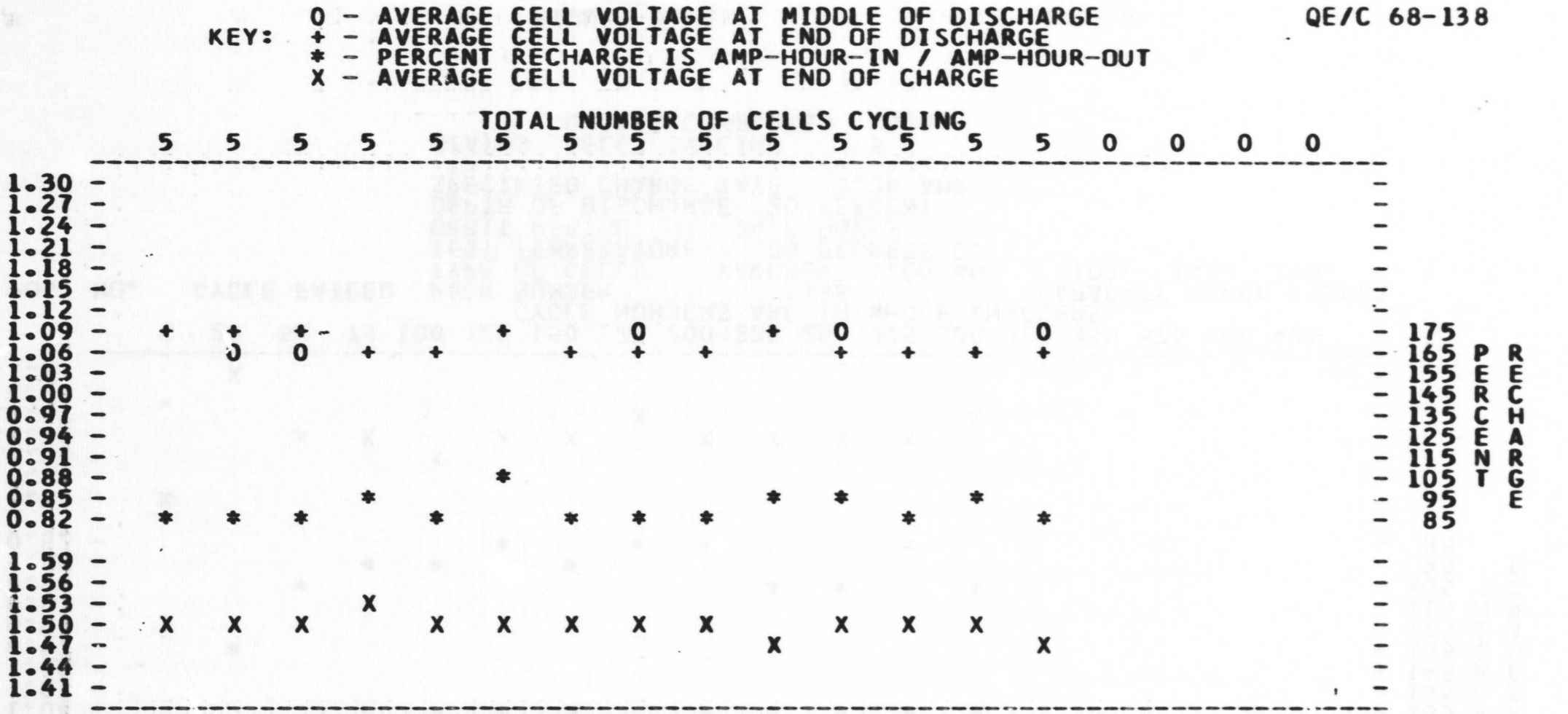

POS. NO. CYCLE FAILED

PACK NUMBER 1138
TYPE OF CELLS YARDNEY 5.00 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 24.0 HOURS
DEPTH OF DISCHARGE 20 PERCENT
SPECIFIED CHARGE RATE 0.30 AMP.

CAPACITY CHECK CYCLES
103, 193, 295,

STATUS CELLS CYCLING 5
CYCLES COMPLETED 328

FIGURE 31(A)




POS. NO. CYCLE FAILED

PACK NUMBER 077B

TYPE OF CELLS YARDNEY 5.00 AH

TEST TEMPERATURE 25 DEGREES C.

ORBIT PERIOD 24.0 HOURS

DEPTH OF DISCHARGE 20 PERCENT

SPECIFIED CHARGE RATE 0.30 AMP.

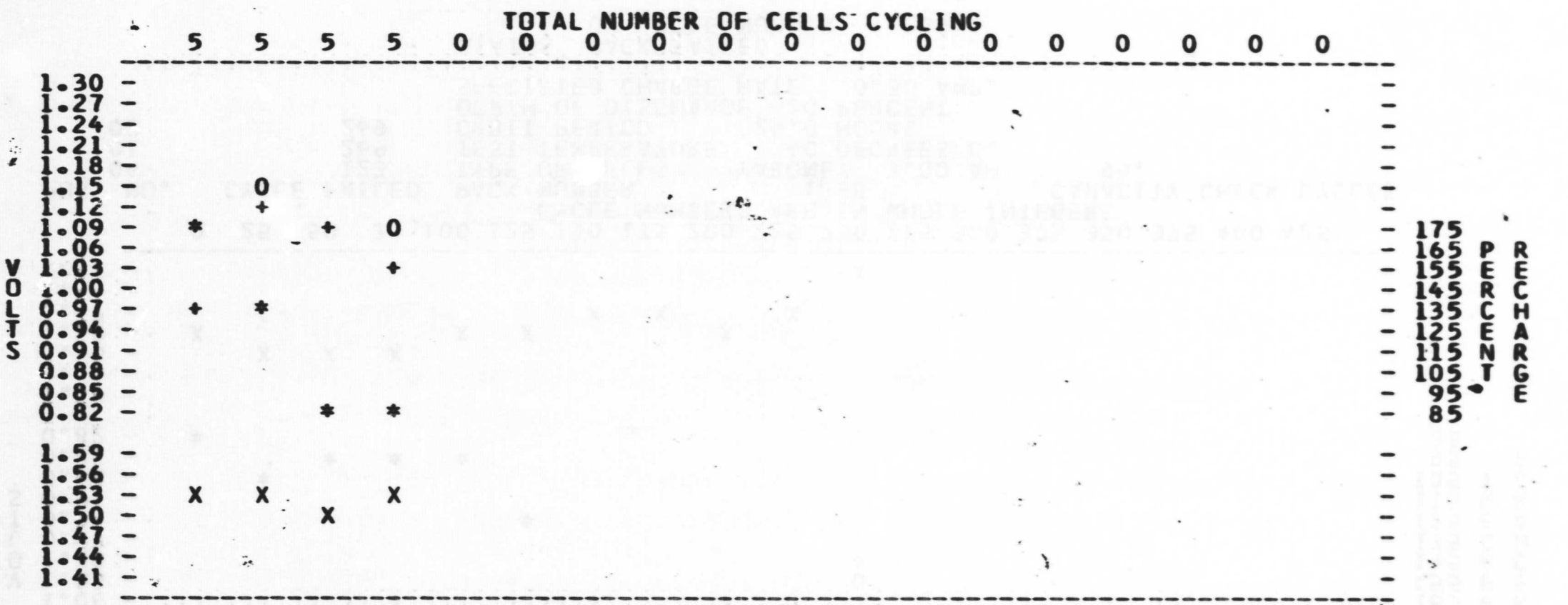
CAPACITY CHECK CYCLES
114, 204, 306,

STATUS CELLS CYCLING 5
CYCLES COMPLETED 339

FIGURE 31(B)

KEY: 0 – AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ – AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* – PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X – AVERAGE CELL VOLTAGE AT END OF CHARGE

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| POS. NO. | CYCLE FAILED |
|---|---|
| 02 | 69 |
| 03 | 77 |
| 05 | 77 |

PACK NUMBER 105B
TYPE OF CELLS YARDNEY 5.00 AH
TEST TEMPERATURE 25 DEGREES C.
ORBIT PERIOD 24.0 HOURS
DEPTH OF DISCHARGE 20 PERCENT
SPECIFIED CHARGE RATE 0.30 AMP.

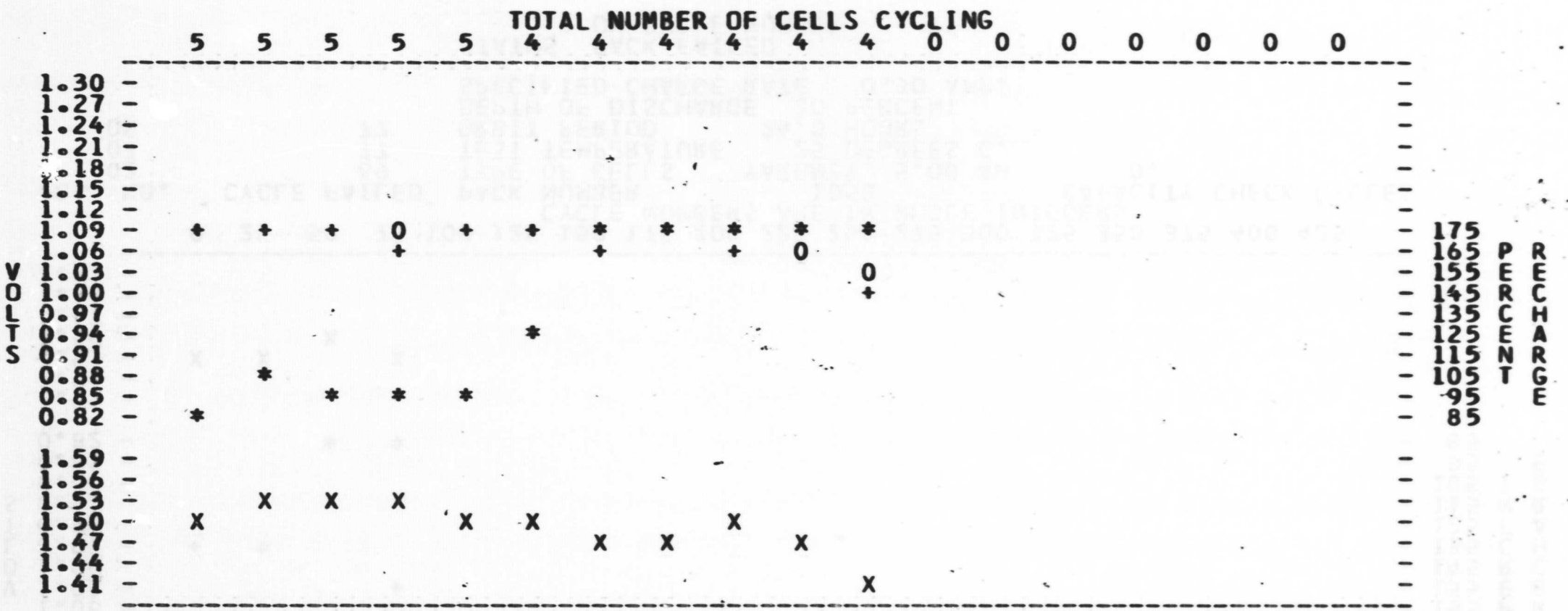
CAPACITY CHECK CYCLES
0,

STATUS PACK FAILED
ON CYCLE NUMBER 77

FIGURE 31(C)

KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE

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| POS. NO. | CYCLE FAILED | | CAPACITY CHECK CYCLES |
|---|---|---|---|
| 04 | 123 | PACK NUMBER 128B | 94, |
| 01 | 269 | TYPE OF CELLS YARDNEY 5.00 AH | |
| 02 | 269 | TEST TEMPERATURE 40 DEGREES C. | |
| | | ORBIT PERIOD 24.0 HOURS | |
| | | DEPTH OF DISCHARGE 20 PERCENT | |
| | | SPECIFIED CHARGE RATE 0.30 AMP. | |

STATUS PACK FAILED
ON CYCLE NUMBER 269

FIGURE 31(D)

6. Yardney 5.0 ah, Two 5-cell Packs, 8-hour Orbit Period:

a. Cell Description: These are vented cells, rectangular in shape, with cell jar and cell cover molded of a plastic material. The separator material is pellon and cellophane. The cells were individually epoxy potted at the Goddard Space Flight Center to hermetically seal them.

b. Test Parameters:

| Pack Number | Test Temperature | Percent Depth of Discharge | Charge Voltage Limit, Per Cell |
|---|---|---|---|
| 114B | 0° C | 20 | 1.50 ± 0.03 |
| 118C | 25° C | 20 | 1.50 ± 0.03 |

c. Test Results:

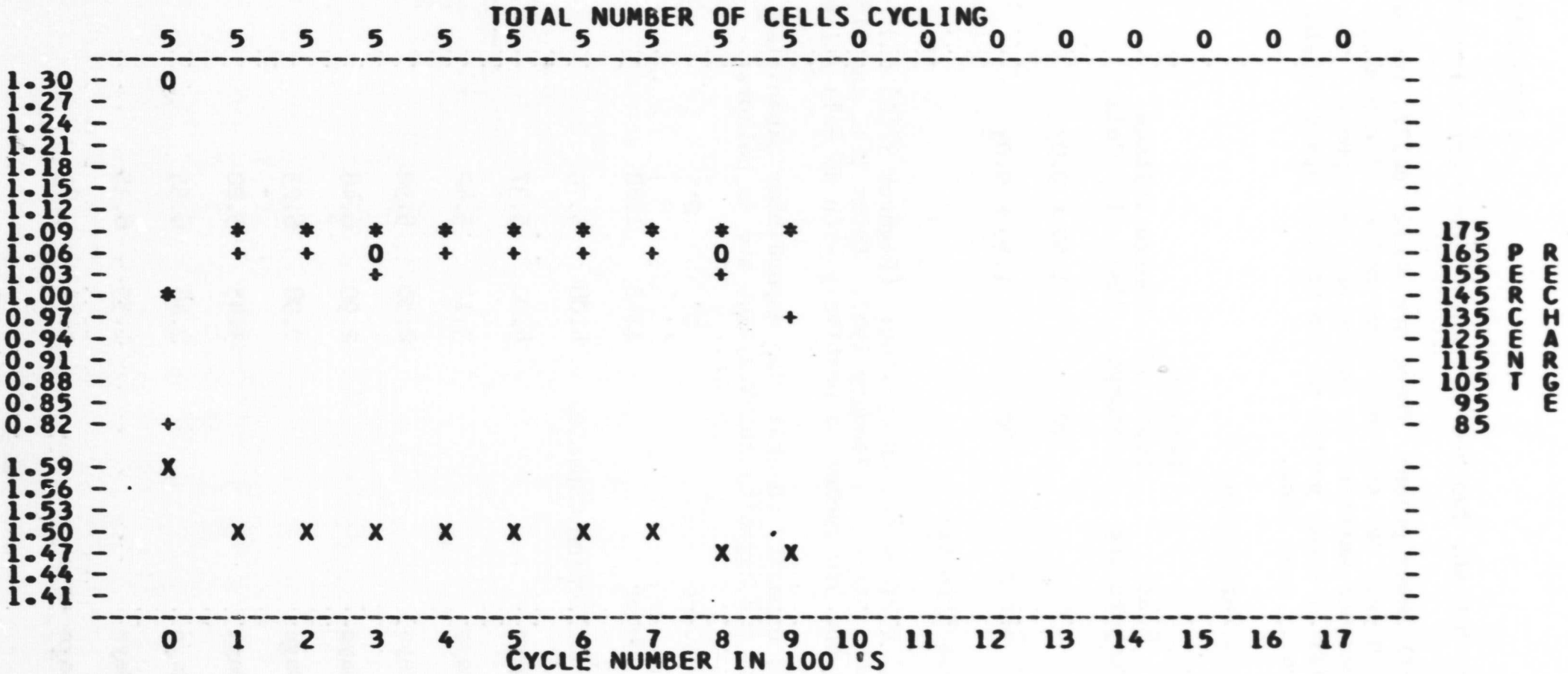
(1) Performance on cycling: (Figures 32(A) and 32(B).) Cycling was started in January 1967. Packs 114B and 118C have completed 954 and 970 cycles respectively with no cell failures.

(2) Capacity checks: The ampere-hour capacities on the preconditioning and capacity check cycles are as follows:

| Temperature | 0° | 25° |
|---|---|---|
| Pack Number | 114B | 118C |
| Preconditioning Capacity | 4.08 | 5.70 |
| 30 Days | 4.00 | 5.37 |
| 60 Days | 3.10 | 5.42 |
| 90 Days | 2.50 | 5.32 |
| 120 Days | 2.90 | 6.48 |
| 150 Days | 2.98 | 6.25 |
| 180 Days | 3.45 | 5.20 |
| 210 Days | 2.48 | 6.55 |
| 240 Days | 1.55 | 6.35 |
| 270 Days | 1.75 | 5.83 |

KEY: 0 – AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ – AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* – PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X – AVERAGE CELL VOLTAGE AT END OF CHARGE

QE/C 68-138




POS. NO. CYCLE FAILED

PACK NUMBER 1148
TYPE OF CELLS YARDNEY 5.00 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 08.0 HOURS
DEPTH OF DISCHARGE 20 PERCENT
SPECIFIED CHARGE RATE 0.30 AMP.

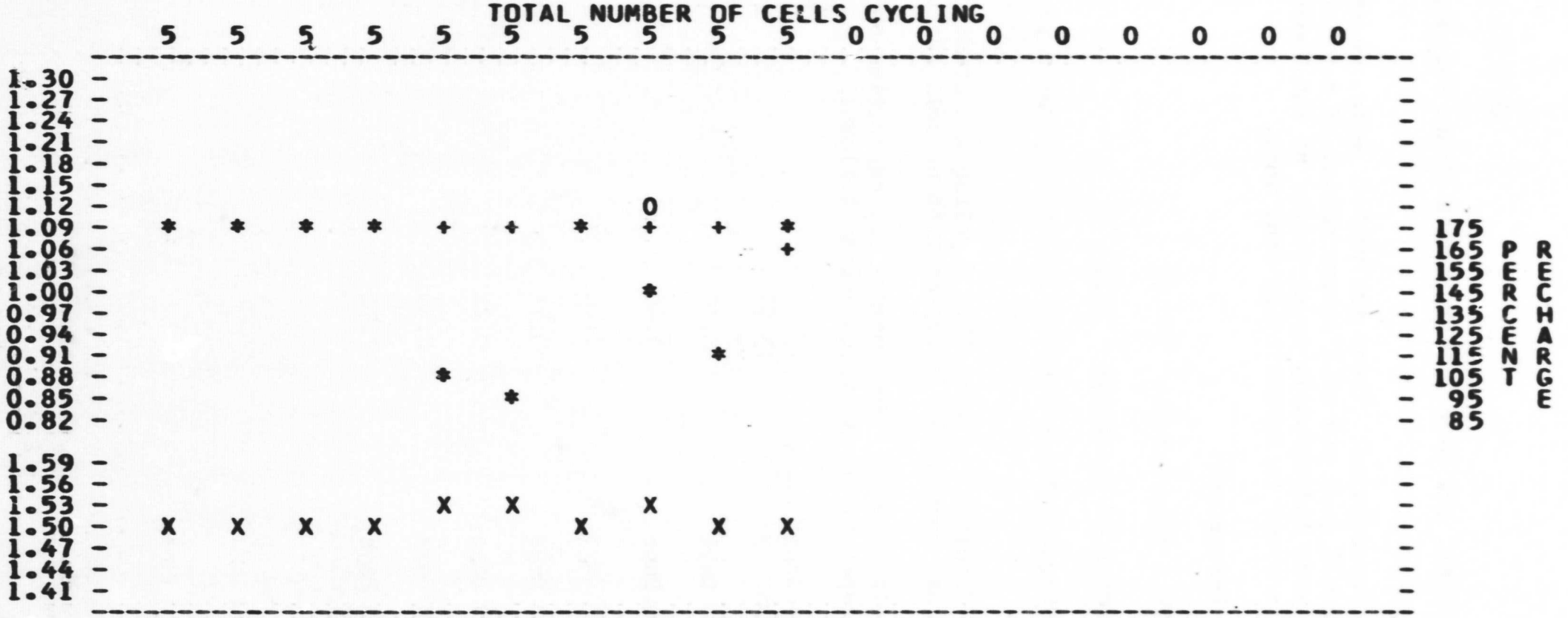
STATUS CELLS CYCLING 5
CYCLES COMPLETED 954

CAPACITY CHECK CYCLES
133, 238, 318, 414, 516
603, 7020, 7830, 8820,

FIGURE 32(A)

KEY: 0 – AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ – AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* – PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X – AVERAGE CELL VOLTAGE AT END OF CHARGE

QE/C 68-138




POS. NO. CYCLE FAILED

PACK NUMBER 118C
TYPE OF CELLS YARDNEY 5.00 AH
TEST TEMPERATURE 25 DEGREES C.
ORBIT PERIOD 08.0 HOURS
DEPTH OF DISCHARGE 20 PERCENT
SPECIFIED CHARGE RATE 0.30 AMP.

CAPACITY CHECK CYCLES
149, 254, 334, 430, 532
619, 718, 799, 898,

STATUS CELLS CYCLING 5
CYCLES COMPLETED 970

FIGURE 32(B)

7. Yardney 10 ah, One 5-cell Pack, 8-hour Orbit Period, (Pack 45D):

a. Cell Description: These are vented cells, rectangular in shape, with cell jars and cell covers molded of a plastic material. The cells were individually epoxy potted at the Goddard Space Flight Center in order to hermetically seal them.

b. Test Parameters:

(1) Test Temperature: 25° C.

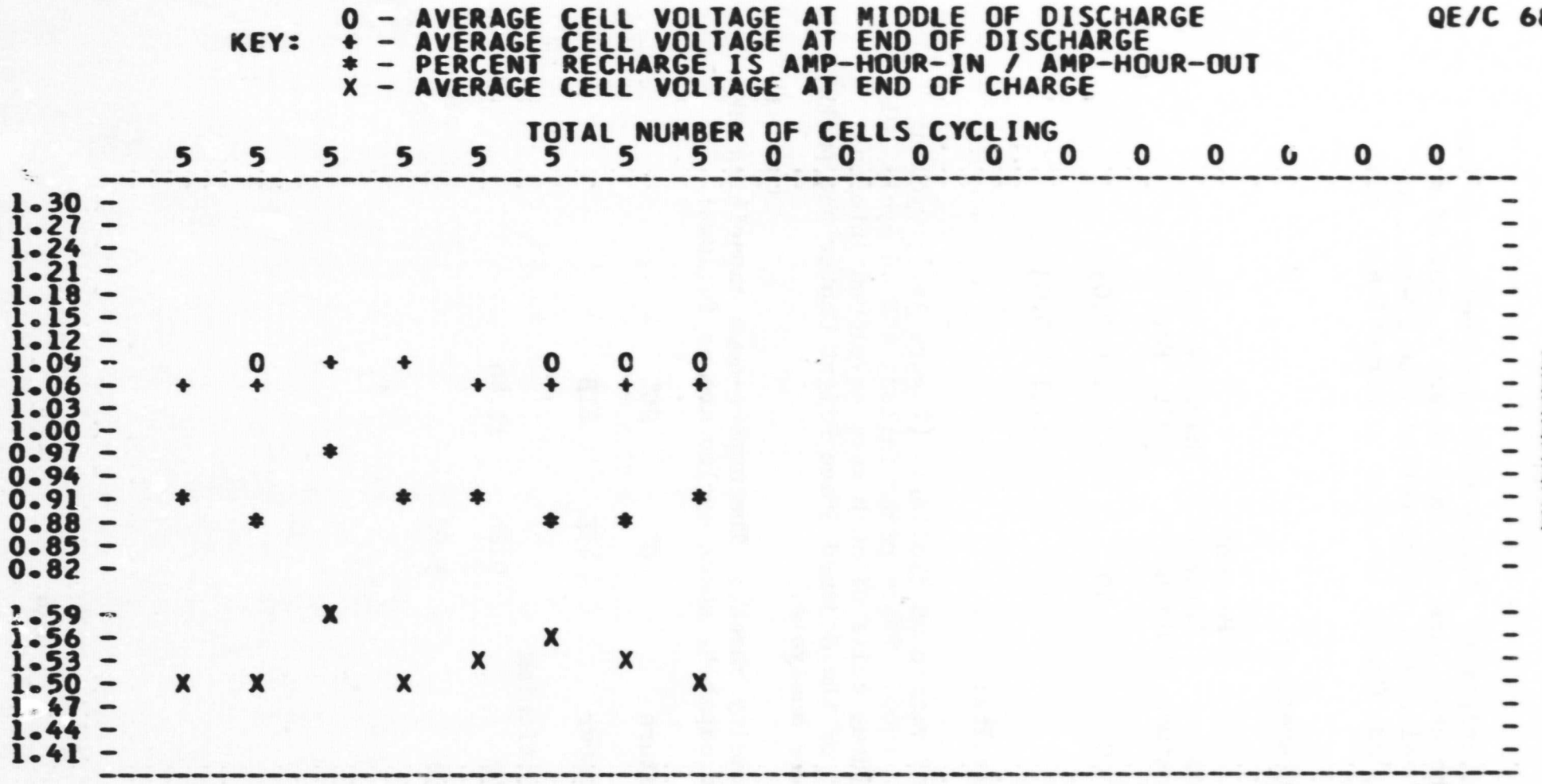
(2) Depth of Discharge: 30%.

(3) Charge Voltage Limit: 1.51 ± 0.03 volts per cell, average.

c. Test Results: (Figure 33.) Cycling was started in May 1967. This pack has completed 851 cycles with no cell failures.

d. Capacity Checks: The ampere-hour capacities on the preconditioning and capacity check cycles are as follows:

| | |
|---|---|
| Preconditioning Capacity | 13.50 |
| 30 Days | 8.90 |
| 60 Days | 9.60 |
| 90 Days | 7.10 |
| 120 Days | 8.45 |
| 150 Days | 9.25 |
| 180 Days | 8.50 |
| 210 Days | 7.70 |




POS. NO. CYCLE FAILED

PACK NUMBER 045D
TYPE OF CELLS YARDNEY 10.00 AH
TEST TEMPERATURE 25 DEGREES C.
ORBIT PERIOD 98.0 HOURS
DEPTH OF DISCHARGE 30 PERCENT
SPECIFIED CHARGE RATE 0.50 AMP.

CAPACITY CHECK CYCLES
0,

STATUS PACK FAILED
ON CYCLE NUMBER 728

FIGURE 33

8. Yardney 11.0 ah, Two 10-cell Packs, 24-hour Orbit Period:

a. Cell Description: These are vented cells, rectangular in shape, with the cell jars and cell covers molded of a plastic material. The cells were epoxy potted into 10-cell packs at the Goddard Space Flight Center in order to hermetically seal them.

b. Test Parameters:

| Pack Number | Test Temperature | Percent Depth of Discharge | Charge Voltage Limit, Per Cell |
|---|---|---|---|
| 45B | 0° C | 40 | 1.51 ± 0.03 |
| 21B | 25° C | 40 | 1.51 ± 0.03 |

c. Test Results:

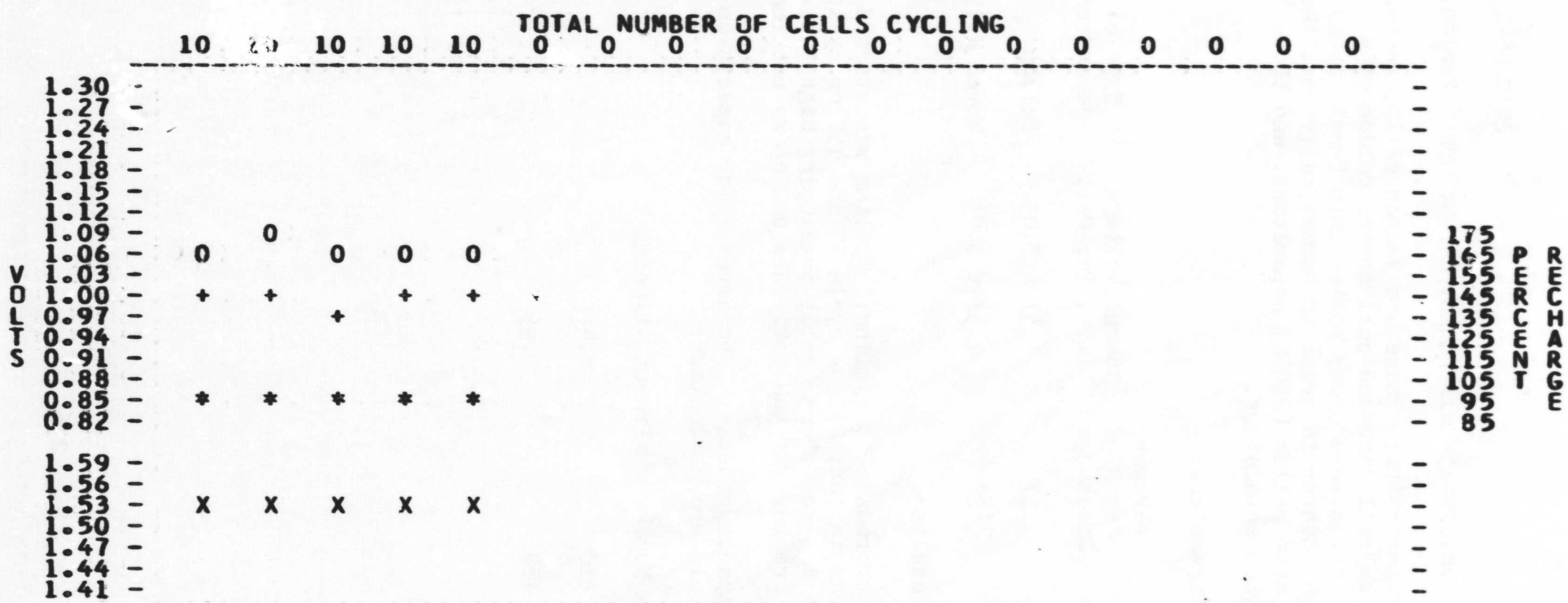
(1) Performance on cycling: (Figure 34.) Cycling was started in November 1966. These packs failed; 45B on cycle 121 and 21B on cycle 69. Three cells of each pack developed internal shorts. At the request of the Goddard Space Flight Center the packs were returned for failure analysis.

(2) Capacity checks: The ampere-hour capacities on the preconditioning and capacity check cycles are as follows:

| Temperature | 0° | 25° |
|---|---|---|
| Pack Number | 45B | 21B |
| Preconditioning Capacity | 9.26 | 11.46 |
| 100 Days | 5.91 | |

KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE

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| POS. NO. | CYCLE FAILED |
|---|---|
| 03 | 121 |
| 04 | 121 |
| 06 | 121 |

PACK NUMBER 045B
TYPE OF CELLS YARDNEY 11.00 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 24.0 HOURS
DEPTH OF DISCHARGE 40 PERCENT
SPECIFIED CHARGE RATE 0.30 AMP.

CAPACITY CHECK CYCLES
115,

STATUS PACK FAILED
ON CYCLE NUMBER 121

FIGURE 34

9. Yardney 11 ah, Two 5-cell Packs, 8-hour Orbit Period:

a. Cell Description: These are vented cells, rectangular in shape, with the cell jars and cell covers molded of a plastic material. The cells were epoxy potted into 5-cell packs at the Goddard Space Flight Center in order to hermetically seal them. The cells of pack 21C have pellon (2505K) separators, and those of pack 45C have woven nylon separators.

b. Test Parameters:

| Pack Number | Test Temperature | Percent Depth of Discharge | Charge Voltage Limit, Per Cell | Type of Separator |
|---|---|---|---|---|
| 21C | 25° C | 27 | 1.51 ± 0.03 | Pellon |
| 45C | 25° C | 27 | 1.51 ± 0.03 | Woven Nylon |

c. Test Results:

(1) Performance on cycling: Cycling was started in March 1967. These packs failed; 21C on cycle 37 and 45C on cycle 70. The failures were due to several cells developing high internal pressure resulting in breakage of the cell jars and epoxy potting.

(2) Capacity checks: The ampere-hour capacities on the preconditioning cycle are as follows:

| Pack Number | Preconditioning |
|---|---|
| 21C | 8.40 |
| 45C | 9.45 |

10. Yardney 12.0 ah, Two 10-cell Packs, 24-hour Orbit Period:

a. Cell Description: These are double sealed rectangular cells. That is, each sealed polystyrene cell is encased in a hermetically sealed stainless steel container.

b. Test Parameters:

| Pack Number | Test Temperature | Percent Depth of Discharge | Charge Voltage Limit, Per Cell |
|---|---|---|---|
| 57A | 0° C | 50 | 1.50 ± 0.03 |
| 33A | 40° C | 50 | 1.50 ± 0.03 |

c. Test Results:

(1) Performance on cycling: Cycling was started in February 1964. These packs failed on cycles 166 and 210.

(a) Pack 57A: Low end-of discharge voltages began on cycle 31 and continued erratically until the pack failed on cycle 166. Although cell voltages had frequently fallen below the 0.5 volt failure point, they had not been classed as failures earlier because of their erratic behavoir. After completion of 162 cycles, electrolyte had leaked out and formed a pool over the tops of the cells, thus shorting them out. The 10 cells were cleaned, after which seven were returned to cycling. After four additional cycles the condition had recurred. All seven cells leaked.

(b) Pack 33A: The plateau voltage of the non-failing cells on discharge was fairly steady at about 1.06 volts per cell for the first 110 cycles with little or no drop off at the end of discharge. Thereafter, the plateau voltage began to drop steadily and the end-of-discharge voltage became quite erratic. This pack failed on cycle 210. All of the failed cells had dried out because of electrolyte leakage.

(2) Capacity checks: The ampere-hour capacities on the preconditioning and capacity check cycles are as follows:

| Pack Number | Preconditioning Capacity | 140 Days Discharge #1 | #2 |
|---|---|---|---|
| 57A | 13.8 | 5.9 | 8.6 |
| 33A | 13.5 | 11.2 | 12.0 |

11. Yardney 12.0 ah, Three 5-cell Packs, 1.5-hour Orbit Period:

a. Cell Description: These are vented cells, rectangular in shape, with cell jars and cell covers molded of a plastic material. The cells were individually epoxy po ed to hermetically seal them.

b. Test Parameters:

(1) Initial Parameters:

| Pack Number | Test Temperature | Percent Depth of Discharge | Charge Voltage Limit, Per Cell |
|---|---|---|---|
| 85B | -20° C | 25 | 1.60 ± 0.03 |
| 97B | 0° C | 25 | 1.58 ± 0.03 |
| 82B | 25° C | 25 | 1.55 ± 0.03 |

(2) Changes in Test Parameters: Due to low end-of-discharge voltage at -20° C prior to cycle 214, the test temperature of Pack 85B was increased to 40° C with a voltage limit of 1.55 ± 0.03 volts per cell, average.

c. Test Results: (Figures 35(A) and 35(B).) Cycling was started in January 1966. These packs have completed from 1442 to 4559 cycles with 10 cell failures.

(1) Due to poor charge acceptance at -20° C, the end-of-discharge voltage dropped below 0.8 volt per cell, average. In order to obtain more data the test parameters of Pack 85B were changed as noted above. The pack then cycled satisfactorily with the end-of-discharge voltage being approximately 1.06 volts per cell, average. The end-of-discharge voltage of the other two packs was also approximately 1.06 volts per cell, average.

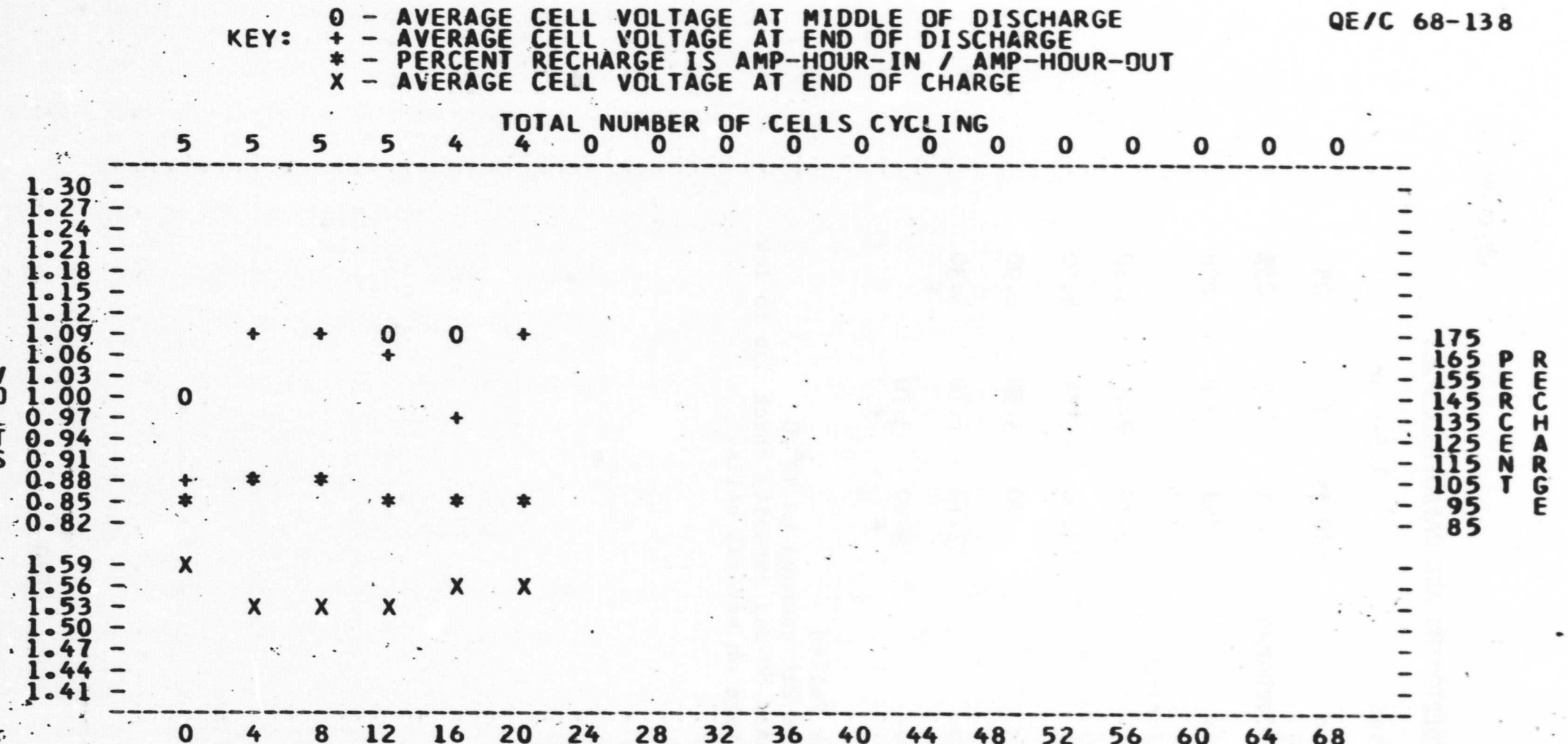
(2) Failure of the 10 cells was caused by silver penetration of the separators.

d. Capacity Checks: The ampere-hour capacities on the preconditioning and capacity check cycles are as follows:

## PRECONDITIONING AND CAPACITY CHECKS

| Orbit Period | | 1.5-hour | |
|---|---|---|---|
| Temperature | -20° ** | 0° | 25° |
| Depth of Discharge | 25% | 25% | 25% |
| Pack Number | 85B | 97B | 82B |
| Preconditioning Capacity | 5.40 | 9.00 | 13.30 |
| 88 Days | 13.80 | *** | 4.50 |
| 176 Days | 8.70 | 3.50 | 2.90 |
| 264 Days | 13.70 | 5.70 | 3.30 * |
| 352 Days | 9.60 * | 3.70 * | |

* Pack Failed
** Cycle 214 changed to 40° C
*** Missed 88-day capacity check due to low voltage on several cells.




POS. NO. CYCLE FAILED
01 1978
02 2245
03 2375
04 2375

PACK NUMBER 085B
TYPE OF CELLS YARDNEY 12.00 AH
TEST TEMPERATURE -20 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 3.90 AMP.

STATUS PACK FAILED
ON CYCLE NUMBER 2375

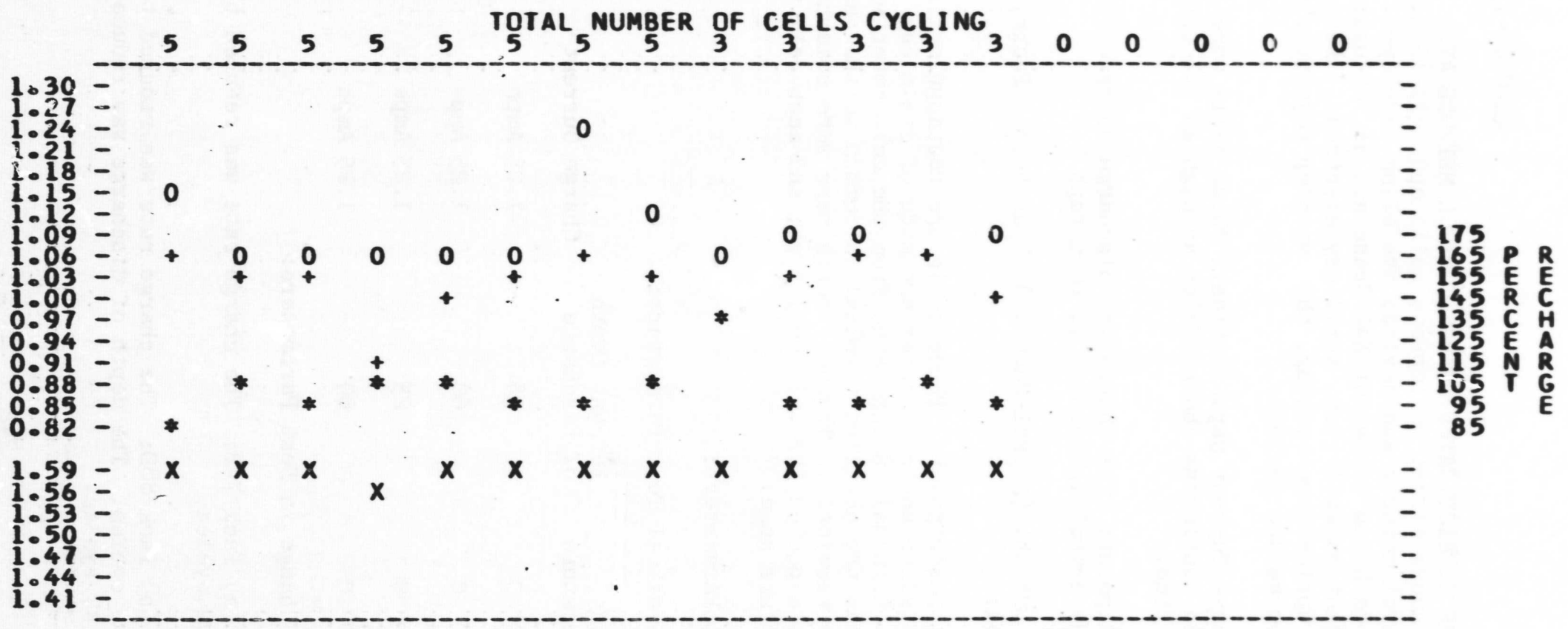
CAPACITY CHECK CYCLES
91, 93, 214, 216,

CYCLE 214 CHANGED TO 40 DEGREES CENTIGRADE, VOLTAGE LIMIT 1.55 VOLTS PER CELL.

FIGURE 35(A)

KEY: O - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE

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| POS. NO. | CYCLE FAILED |
|---|---|
| 01 | 2972 |
| 02 | 3186 |
| 04 | 4481 |

PACK NUMBER 097B
TYPE OF CELLS YARDNEY 12.00 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 3.90 AMP.

CAPACITY CHECK CYCLES
76, 664, 2133, 3131, 4446
0,

STATUS PACK FAILED
ON CYCLE NUMBER 4481

FIGURE 35(B)

**II. CELLS USING MORE SOPHISTICATED CHARGE CONTROL METHODS AND DEVICES:** As a continuous effort to improve cells and cell life, new types of charge control methods and devices are being developed. Charge control methods being tested at NAD Crane are as follows: high overcharge current capabilities, auxiliary electrode, stabistor, coulometer, Sherfey upside-down cycling, the two-step regulator and internal mechanical pressure devices.

A. High Overcharge Current Capabilities: These cells were constructed to withstand continuous charge rates as high as c/1 for extended periods of time.

1. Test Equipment: The charge and discharge current is supplied by a unit described in section I, paragraph V.b.

2. Gulton 1.25 ah, (Nickel-Cadmium), Four 5-cell Packs, 1.5-hour Orbit Period:

a. Cell Description: These cells are rectangular in shape. The cell container and cell cover are made of stainless steel. The positive terminal is insulated from the cell cover by a ceramic seal whereas the negative terminal is common to the can. Both are solder type terminals. The cell containers were somewhat larger than normally expected for this cell size; and each cell was equipped with a pressure gage.

b. Test Parameters:

(1) Initial Test Parameters:

| Pack Number | Test Temperature | Percent Depth of Discharge | Charge Current |
|---|---|---|---|
| 74B | -20° C | 25 | 1.25 Amps |
| 88D | -20° C | 60 | 1.25 Amps |
| 108B | 0° C | 25 | 1.25 Amps |
| 98B | 0° C | 60 | 1.25 Amps |

(2) Change in Test Parameters:

(a) Pack 74B: The charge rate was reduced to 1.0 ampere after five cycles.

(b) Pack 88D: The charge rate was reduced to 1.0 ampere after five cycles. The depth of discharge was reduced to 25 percent after 47 cycles.

c. Test Results:

(1) Performance on cycling: (Figures 36(A) through 36(D).) Cycling was started in March 1966. These packs have completed from 9161 to 10,062 cycles with three cell failures.

(a) Initially, the cells cycling at -20° C developed high internal pressure. After this pressure was relieved several times, and with the reduction of the charge current, the cell pressure remained low.

(b) All three cell failures had severe migration of the negative plate material and blistering on the positive plates. Two cells in pack 98B showed signs of high internal pressure.

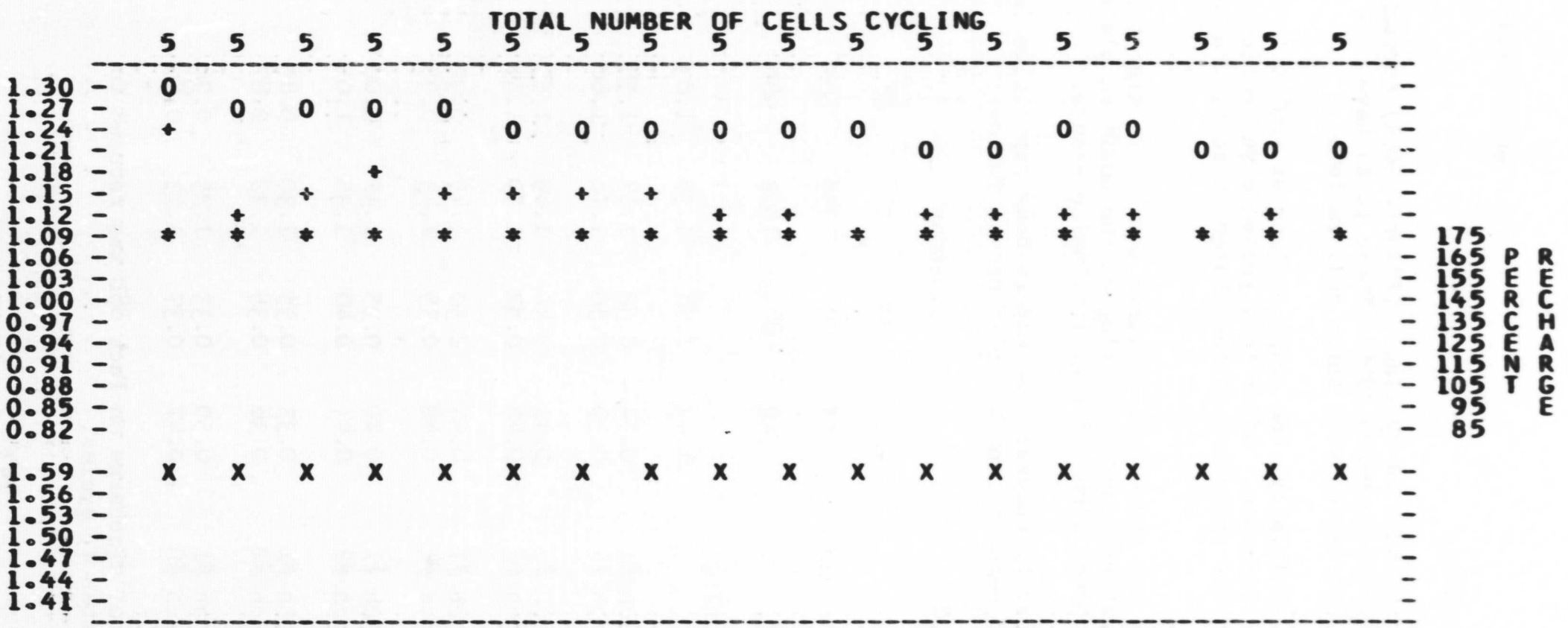
(2) Capacity checks: The ampere-hour capacities on the preconditioning and capacity check cycles are as follows:

| Orbit Period | | 1.5-hour | | | |
|---|---|---|---|---|---|
| Temperature | | -20° | -20° | 0° | 0° |
| Depth of Discharge | | 25% | 60%* | 25% | 60% |
| Pack Number | | 74B | 88D | 108B | 98B |
| Preconditioning Capacity | | 1.43 | 1.28 | 1.78 | 1.83 |
| 88 Days | Disch #1 | 0.54 | 0.52 | 1.67 | 1.58 |
| | Disch #2 | 0.39 | 0.36 | 1.76 | 1.60 |
| 176 Days | Disch #1 | 0.41 | 0.40 | 1.69 | 1.53 |
| | Disch #2 | 0.42 | 0.52 | 1.59 | 1.39 |
| 264 Days | Disch #1 | 0.32 | 0.30 | 1.45 | 0.92 |
| | Disch #2 | 0.40 | 0.35 | 1.43 | 0.95 |
| 352 Days | Disch #1 | 0.40 | 0.35 | 1.32 | 1.08 |
| | Disch #2 | 0.47 | 0.40 | 1.35 | 1.05 |
| 440 Days | Disch #1 | 0.33 | 0.35 | 1.30 | 0.85 |
| | Disch #2 | 0.36 | 0.35 | 1.32 | 0.87 |
| 528 Days | Disch #1 | 0.50 | 0.33 | 1.25 | 0.96 |
| | Disch #2 | 0.47 | 0.37 | 1.13 | 0.86 |

* Depth of discharge on Pack 88D was reduced to 25% after 47 cycles.

KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE

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POS. NO. CYCLE FAILED

PACK NUMBER 074B
TYPE OF CELLS GULTON 1.25 AH
TEST TEMPERATURE -20 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 1.00 AMP.

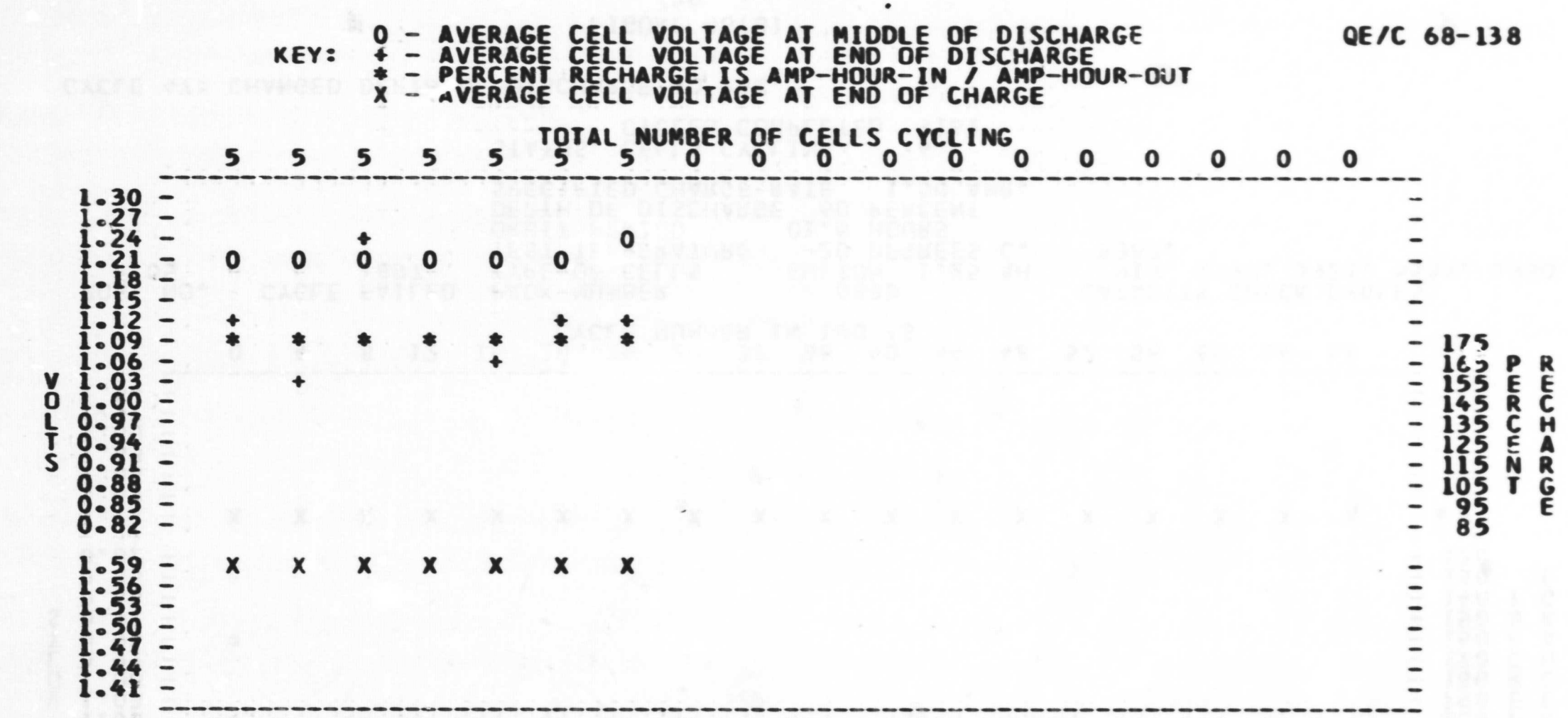
STATUS CELLS CYCLING 5
CYCLES COMPLETED 9772

CAPACITY CHECK CYCLES
1324, 2593, 4532, 6165, 7541
8948,

FIGURE 36(A)

KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE

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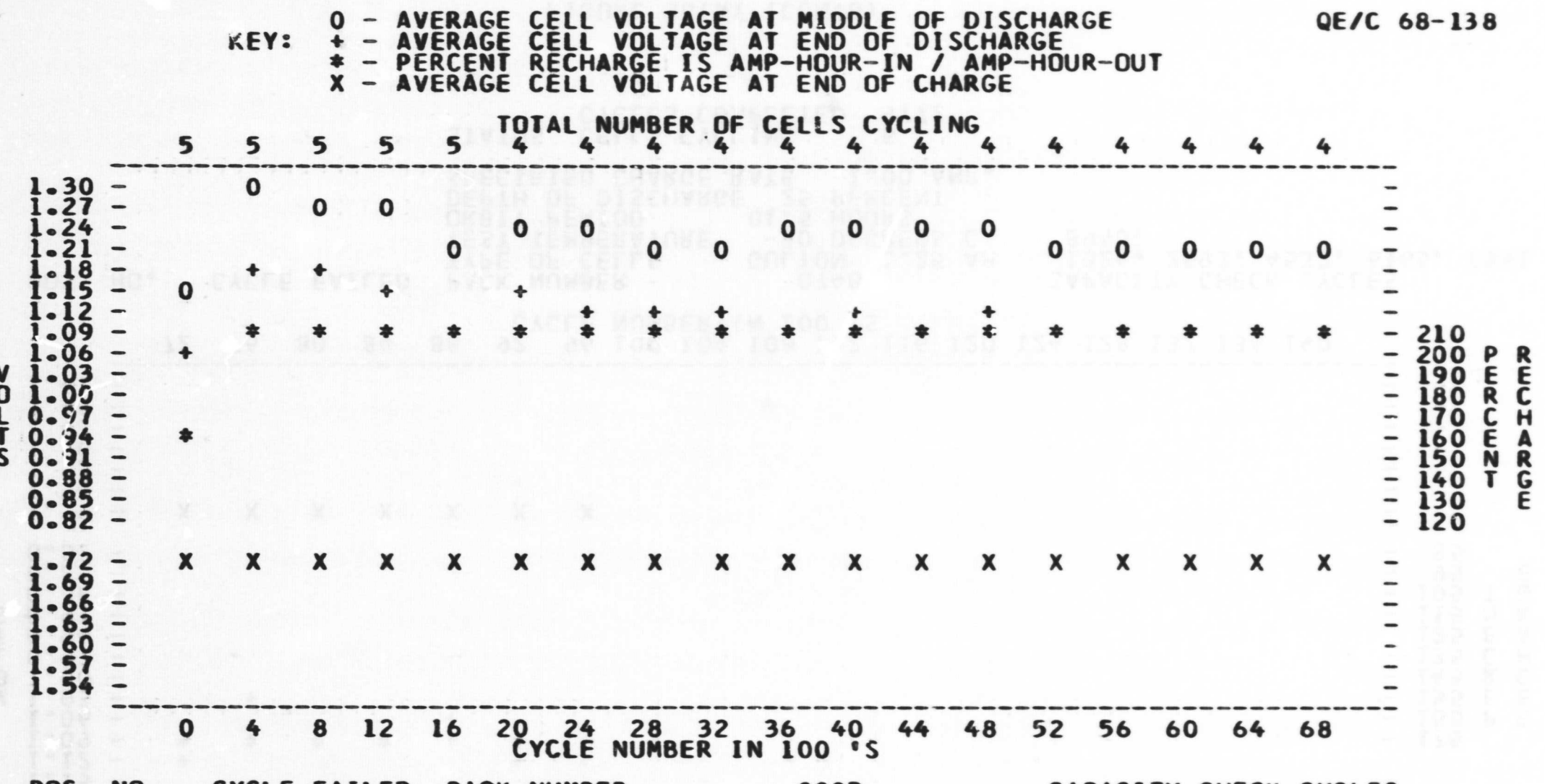

POS. NO. CYCLE FAILED

PACK NUMBER 074B
TYPE OF CELLS GULTON 1.25 AH
TEST TEMPERATURE -20 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 1.00 AMP.

CAPACITY CHECK CYCLES
1324, 2593, 4532, 6165, 7541
8948,

STATUS CELLS CYCLING 5
CYCLES COMPLETED 9772

FIGURE 36(A) (CONTD)




POS. NO. 05 CYCLE FAILED 1897

PACK NUMBER 088D
TYPE OF CELLS GULTON 1.25 AH
TEST TEMPERATURE -20 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 60 PERCENT
SPECIFIED CHARGE RATE 1.00 AMP.

STATUS CELLS CYCLING 4
CYCLES COMPLETED 9161

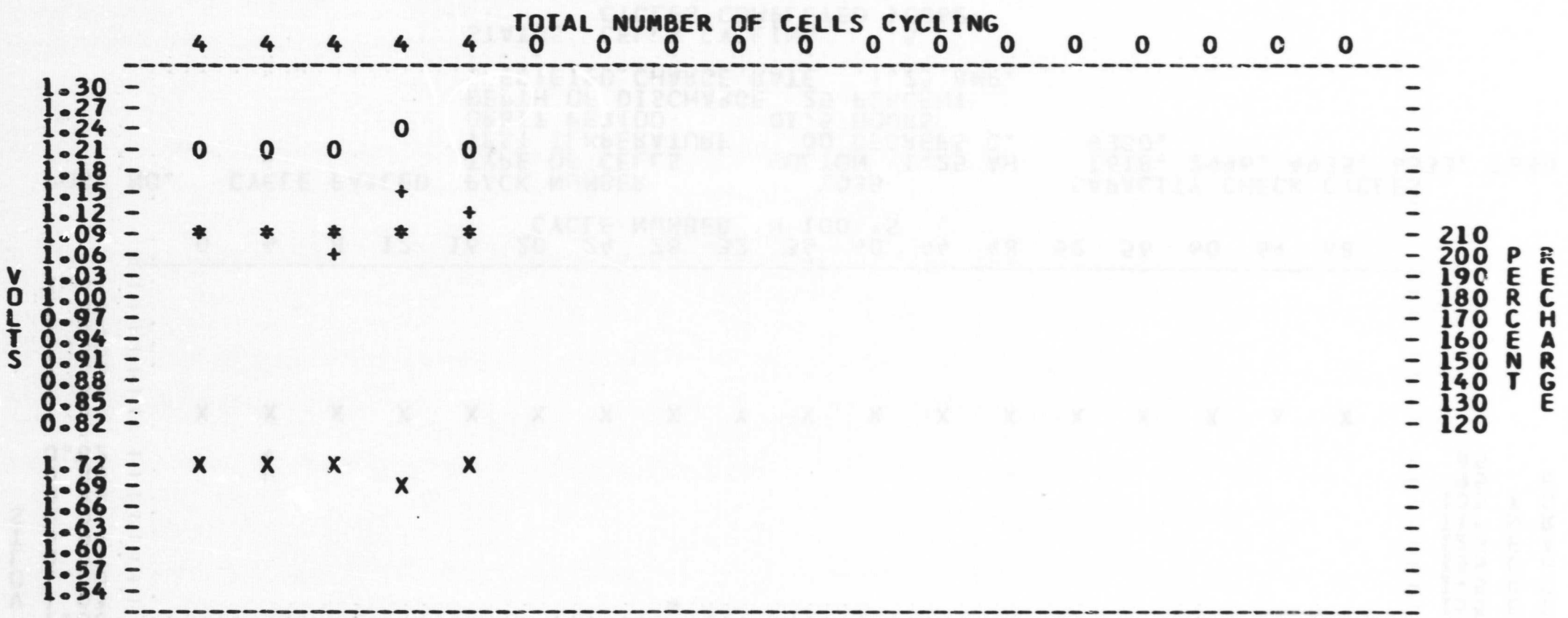
CAPACITY CHECK CYCLES
914, 1992, 3921, 5554, 6930
8367,

CYCLE 47: CHANGED DEPTH OF DISCHARGE TO 25%.

FIGURE 36(B)

KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE

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POS. NO. 05 — CYCLE FAILED 1897

PACK NUMBER 088D
TYPE OF CELLS GULTON 1.25 AH
TEST TEMPERATURE -20 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 60 PERCENT
SPECIFIED CHARGE RATE 1.00 AMP.

STATUS CELLS CYCLING 4
CYCLES COMPLETED 9161

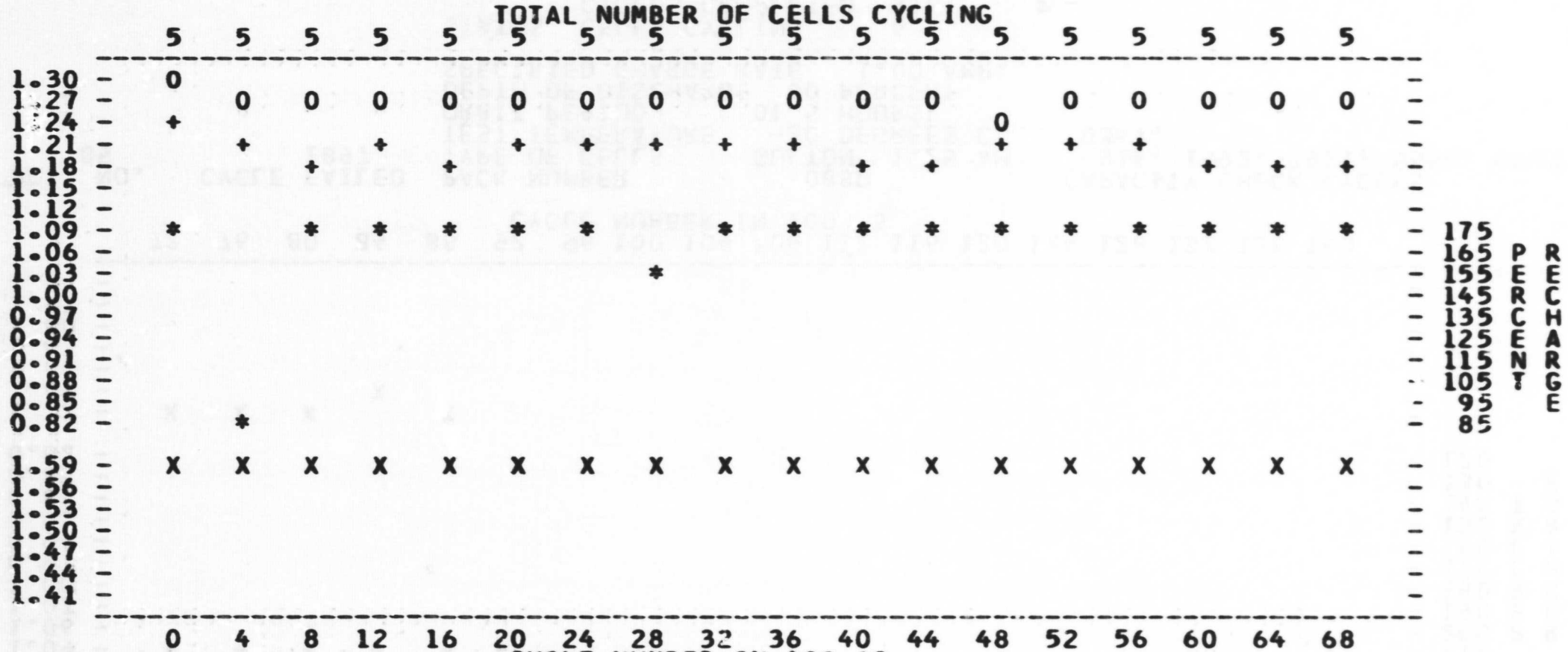
CAPACITY CHECK CYCLES
914, 1992, 3921, 5554, 6930
8367,

CYCLE 47: CHANGED DEPTH OF DISCHARGE TO 25%.

FIGURE 36(B) (CONTD)

KEY: 0 – AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ – AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* – PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X – AVERAGE CELL VOLTAGE AT END OF CHARGE

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POS. NO. CYCLE FAILED

PACK NUMBER 108B
TYPE OF CELLS GULTON 1.25 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 1.25 AMP.

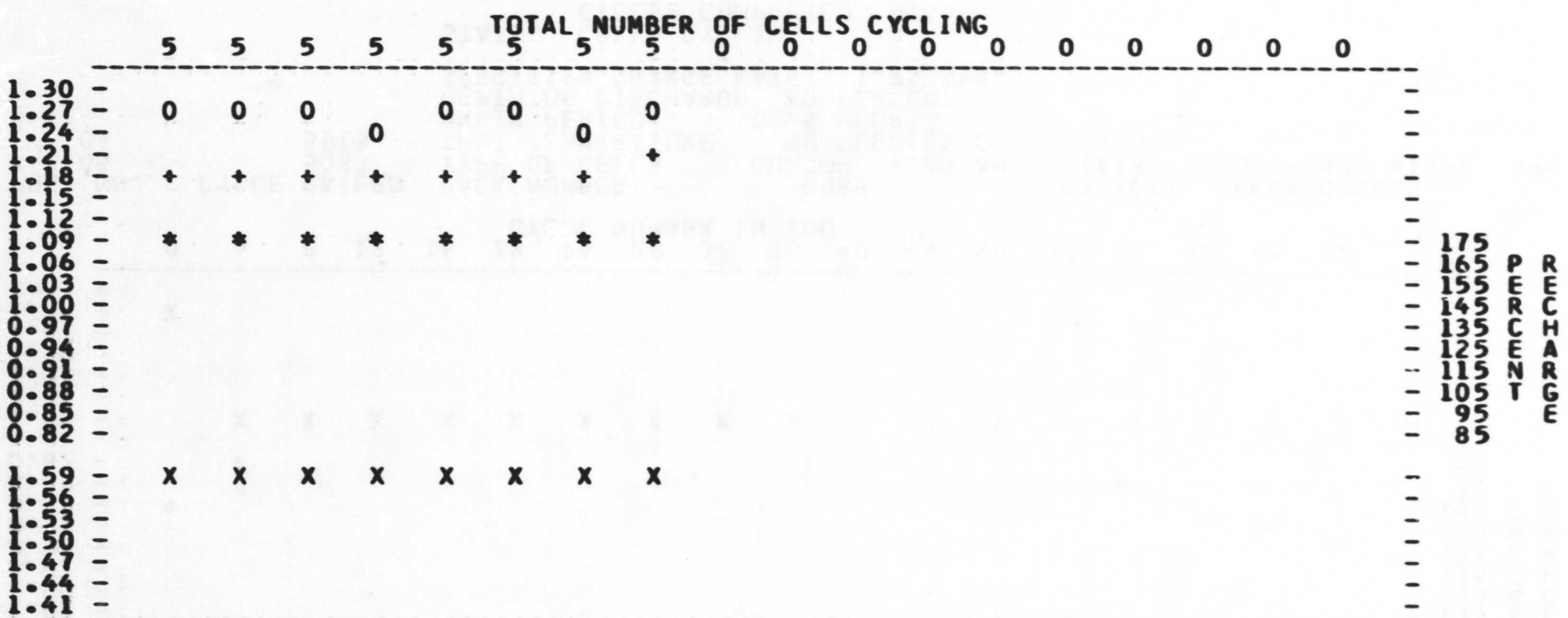
STATUS CELLS CYCLING 5
CYCLES COMPLETED 10062

CAPACITY CHECK CYCLES
1618, 2996, 4935, 6533, 7860
9350,

FIGURE 36(C)

KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE

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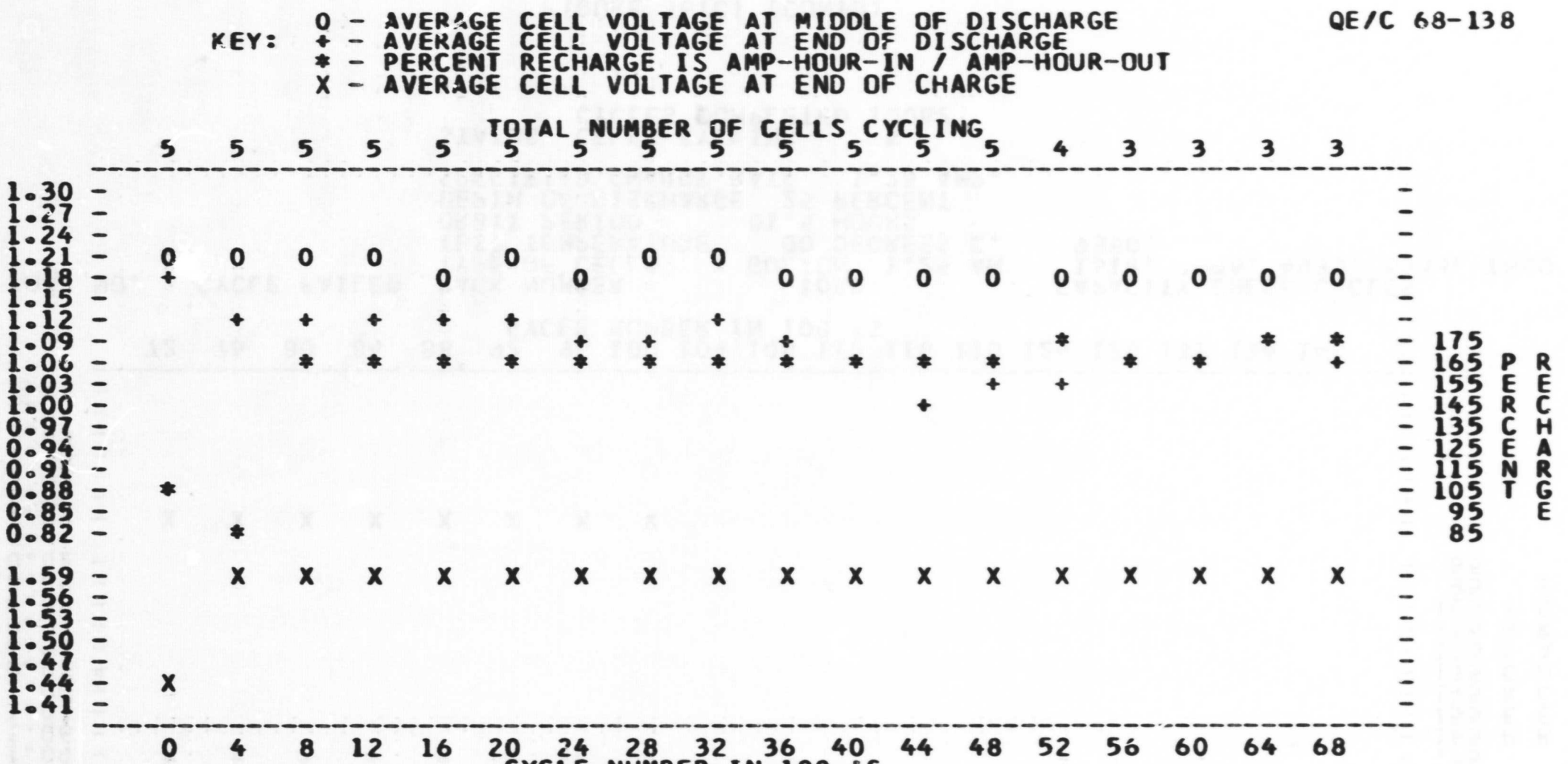

POS. NO. CYCLE FAILED

PACK NUMBER 1088
TYPE OF CELLS GULTON 1.25 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 1.25 AMP.

CAPACITY CHECK CYCLES
1618, 2996, 4935, 6533, 7860
9350,

STATUS CELLS CYCLING 5
CYCLES COMPLETED 10062

FIGURE 36(C) (CONTD)



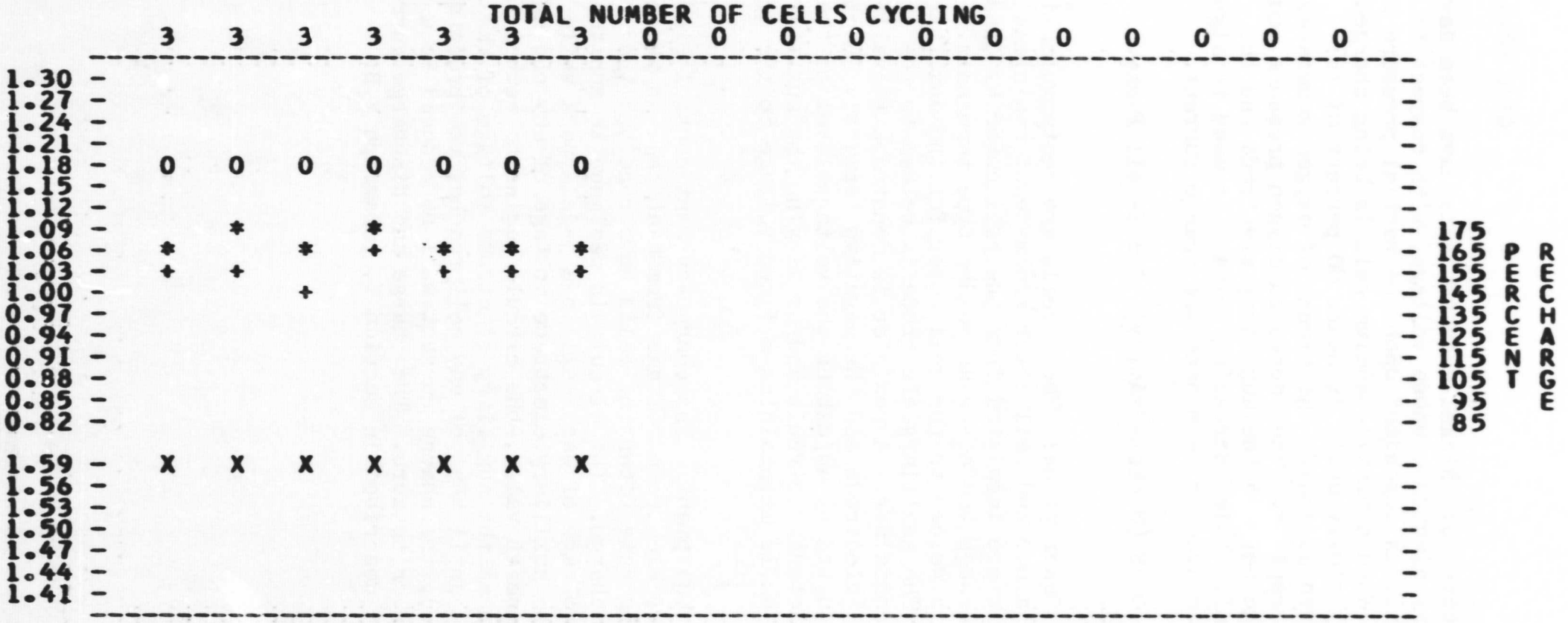

| POS. NO. | CYCLE FAILED | | |
|---|---|---|---|
| 05 | 5033 | PACK NUMBER | 0988 |
| 04 | 5513 | TYPE OF CELLS | GULTON 1.25 AH |
| | | TEST TEMPERATURE | 00 DEGREES C. |
| | | ORBIT PERIOD | 01.5 HOURS |
| | | DEPTH OF DISCHARGE | 60 PERCENT |
| | | SPECIFIED CHARGE RATE | 1.25 AMP. |
| | | STATUS CELLS CYCLING | 3 |
| | | CYCLES COMPLETED | 9746 |

CAPACITY CHECK CYCLES
1618, 2996, 4952, 6169, 7496
8903,

FIGURE 36(D)

KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE

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| POS. NO. | CYCLE FAILED |
|---|---|
| 05 | 5033 |
| 04 | 5513 |

PACK NUMBER 098B
TYPE OF CELLS GULTON 1.25 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 60 PERCENT
SPECIFIED CHARGE RATE 1.25 AMP.

CAPACITY CHECK CYCLES
1618, 2996, 4952, 6169, 7496
8903,

STATUS CELLS CYCLING 3
CYCLES COMPLETED 9746

FIGURE 36(D) (CONTD)

B. Auxilia Electrode: Nickel-cadmium cells have been developed with an auxiliary electrode whose voltage, with respect to the negative cell terminal, is dependent upon the partial pressure of oxygen in the cell. When a nickel-cadmium cell is being charged, it generates oxygen very slowly until it nears 80 percent of the required recharge; then suddenly, the amount of oxygen generated internally increases rapidly. The increased oxygen pressure causes a fast rise in voltage between the auxiliary electrode and the negative cell terminal. This increasing voltage is used to signal a control circuit to reduce or terminate the charge current.

1. Gulton 6.0 ah (Nickel-Cadmium), Six 5-cell Packs, 1.5-hour Orbit Period:

a. Cell Description: These cells are rectangular in shape. The cell container and cell cover are made of stainless steel. Both terminals are insulated from the cell cover by ceramic seals and protrude through the cover as solder type terminals. A stainless steel tab is welded to the cell cover for the auxiliary electrode terminal. The auxiliary electrode is welded to the inner surface of the cell container. A resistor is mounted externally between the auxiliary electrode and the negative terminal. Recharge percentage may be adjusted by adjusting the voltage level of the auxiliary electrode detector circuit and/or varying the auxiliary electrode resistance while maintaining a fixed voltage to the detector circuit.

b. Test Equipment: The charge-current control circuit utilizes the auxiliary electrode voltage from each cell in the pack to reduce the charging rate after the cells have received the predetermined amount of recharge. The circuit is designed to monitor the auxiliary electrode voltage of each cell in a 5-cell pack while being charged. As the auxiliary electrode voltage of any one cell of the pack rises to a preset value, the circuit begins to reduce the charge current. Then as the auxiliary electrode voltage of the cells continues to increase until that of any cell reaches the predetermined maximum (trip voltage), the charge current will be reduced to a preset trickle charge or to zero. The charge and discharge current is supplied by a unit described in section I, paragraph V.B.

c. Test Parameters:

| Pack Number | Test Temperature | Percent Depth of Discharge | Signal Voltage Level (Millivolts) | Resistors On Cells (Ohms) 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|---|
| 59A | 0° C | 25 | 150 | 10 | 10 | 10 | 10 | 10 |
| 71A | 0° C | 40 | 150 | 10 | 10 | 10 | 10 | 10 |
| 23A | 25° C | 25 | 300 | 12 | 18 | 20 | 29 | 24 |
| 11A | 25° C | 40 | 300 | 24 | 24 | 10 | 8 | 24 |
| 35A | 40° C | 15 | 70 | 47 | 47 | 47 | 47 | 47 |
| 47A | 40° C | 25 | 300 | 11 | 11 | 12 | 11 | 11 |

d. Test Results:

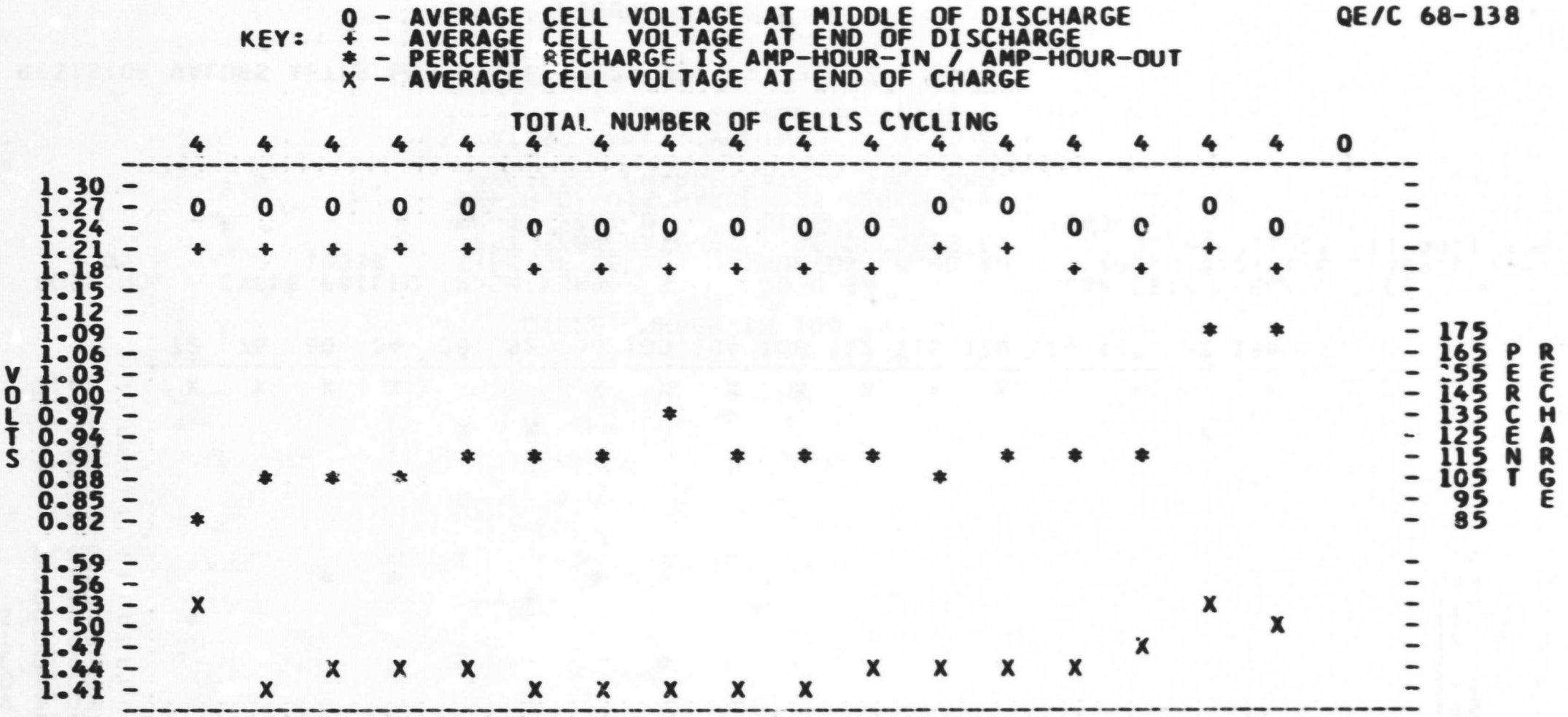
(1) Performance on cycling: (Figures 37(A) through 37(C).) Cycling was started in February 1965. These packs have completed from 5521 to 15,132 cycles with 15 cell failures. Ten of the 15 failed cells had deposits around the ceramic seal. Migration of the negative plate material, blistering of the positive plates, and separator deterioration were the remaining failure conditions found in these cells.

(2) Capacity checks: The ampere-hour capacities on the preconditioning and capacity check cycles are as follows:

## PRECONDITIONING AND CAPACITY CHECKS

| Orbit Period | | 1.5-hour | | | | | |
|---|---|---|---|---|---|---|---|
| Temperature | | 0° | 0° | 25° | 25° | 40° | 40° |
| Depth of Discharge | | 25% | 40% | 25% | 40% | 15% | 25% |
| Pack Number | | 59A | 71A | 23A | 11A | 35A | 47A |
| 100 Cycles | Disch #1 | 6.90 | 7.05 | 3.40 | 4.12 | 2.85 | 3.95 |
| | Disch #2 | 7.15 | 7.25 | ** | ** | 2.95 | 3.65 |
| 88 Days | Disch #1 | 6.25 | 6.70 | 3.24 | 7.10 | 1.80 | 1.70 |
| | Disch #2 | 7.00 | 7.50 | 5.95 | 5.50 | 2.25 | 2.10 |
| 176 Days | Disch #1 | 6.20 | 6.60 | 2.25 | 2.50 | 1.45 | 2.05 |
| | Disch #2 | 3.50 | 7.00 | 3.85 | 3.15 | 1.60 | 1.70 |
| 264 Days | Disch #1 | 6.10 | 4.80 | 1.90 | 2.70 | 1.10 | 1.95 |
| | Disch #2 | 6.75 | 5.65 * | 5.20 | 6.20 | 1.85 | 2.25 * |
| 352 Days | Disch #1 | 5.85 | | 2.05 | 2.60 | 1.20 | |
| | Disch #2 | 6.50 | | 4.00 | 4.35 | 2.00 | |
| 440 Days | Disch #1 | 6.30 | | 2.15 | 2.80 | 1.45 | |
| | Disch #2 | 6.85 | | 4.45 | 3.95 | 2.75 | |
| 528 Days | Disch #1 | 6.90 | | 2.45 | 2.70 | 1.75 | |
| | Disch #2 | 7.00 | | 4.20 | 2.75 * | 2.80 | |
| 616 Days | Disch #1 | 6.00 | | 2.10 | | 1.20 | |
| | Disch #2 | 6.35 | | 3.85 | | 2.20 | |
| 704 Days | Disch #1 | 4.90 | | 2.55 | | 0.99 | |
| | Disch #2 | 6.10 | | 4.40 | | 1.50 | |
| 792 Days | Disch #1 | 5.25 | | 2.05 | | 2.20 | |
| | Disch #2 | 5.50 | | 2.45 | | 2.55 * | |
| 880 Days | Disch #1 | | | 2.50 | | | |
| | Disch #2 | | | 1.50 | | | |
| 968 Days | Disch #1 | | | 1.25 | | | |
| | Disch #2 | | | 1.00 | | | |

* Pack Failed
** Only one discharge run on these packs.




POS. NO. 03

CYCLE FAILED 3202

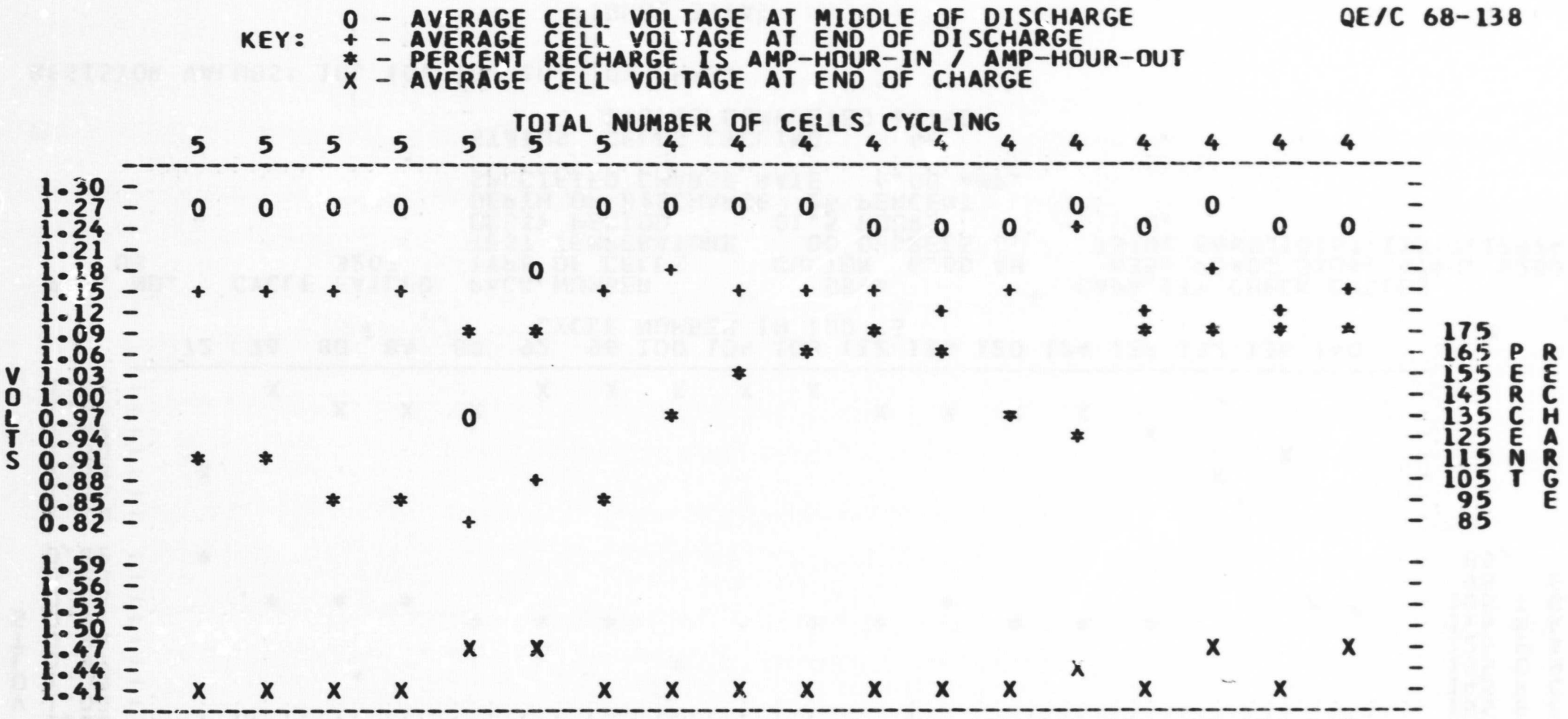
PACK NUMBER 059A
TYPE OF CELLS GULTON 6.00 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 6.00 AMP.

STATUS CELLS CYCLING 4
CYCLES COMPLETED 13750

CAPACITY CHECK CYCLES
635, 2040, 3104, 4749, 6280
7310, 8689, 10167, 11517, 12924
0,

RESISTOR VALUES: 10, 10, 10, 10, 10, OHMS.

FIGURE 37(A)




POS. NO. 05 — CYCLE FAILED 10338

PACK NUMBER 023A
TYPE OF CELLS GULTON 6.00 AH
TEST TEMPERATURE 25 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 3.00 AMP.

STATUS CELLS CYCLING 4
CYCLES COMPLETED 15132

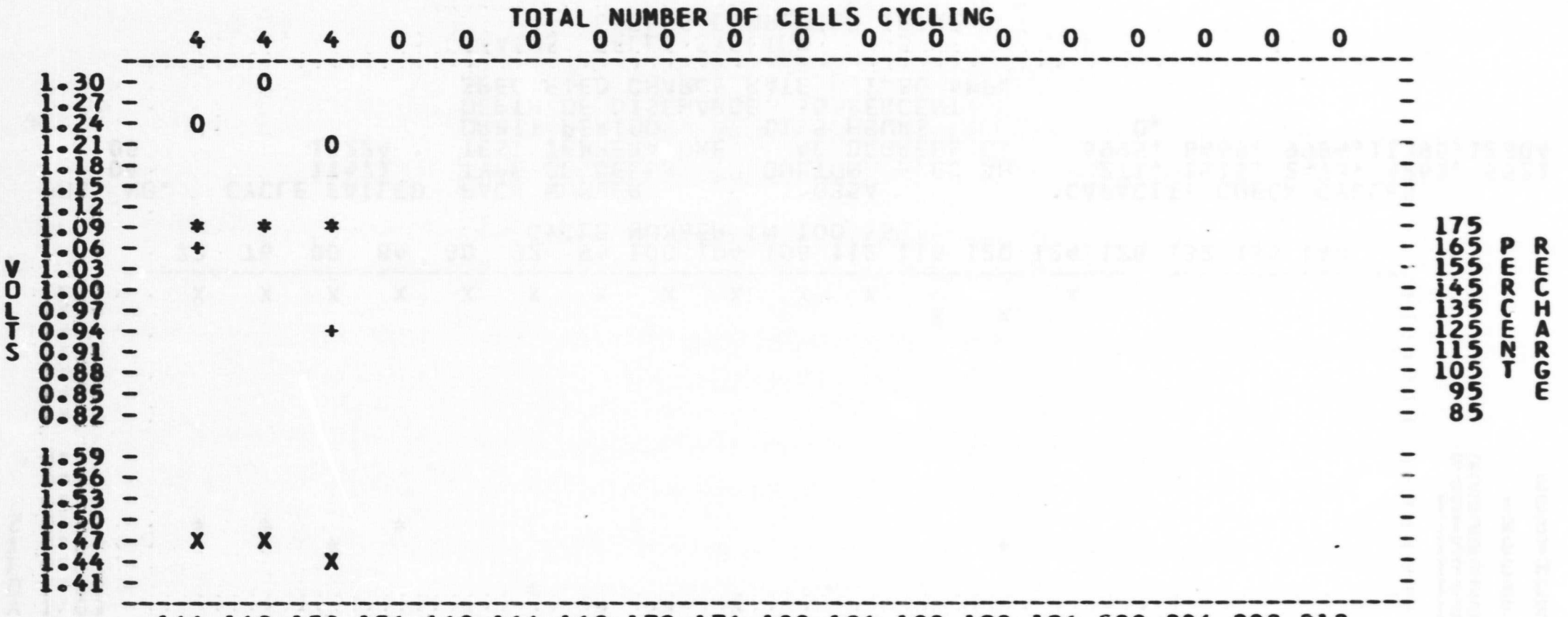
CAPACITY CHECK CYCLES
103, 332, 1268, 3897, 5484
7079, 8649, 10050, 11709, 12899
14306,

RESISTOR VALUES AFTER 853 CYCLES: 12, 12, 20, 29, 24 OHMS.

FIGURE 37(B)

KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE

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POS. NO. 05 — CYCLE FAILED 10338

PACK NUMBER 023A
TYPE OF CELLS GULTON 6.00 AH
TEST TEMPERATURE 25 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 3.00 AMP.

CAPACITY CHECK CYCLES
103, 332, 1268, 3897, 5484
7079, 8649, 10050, 11709, 12899
14306,

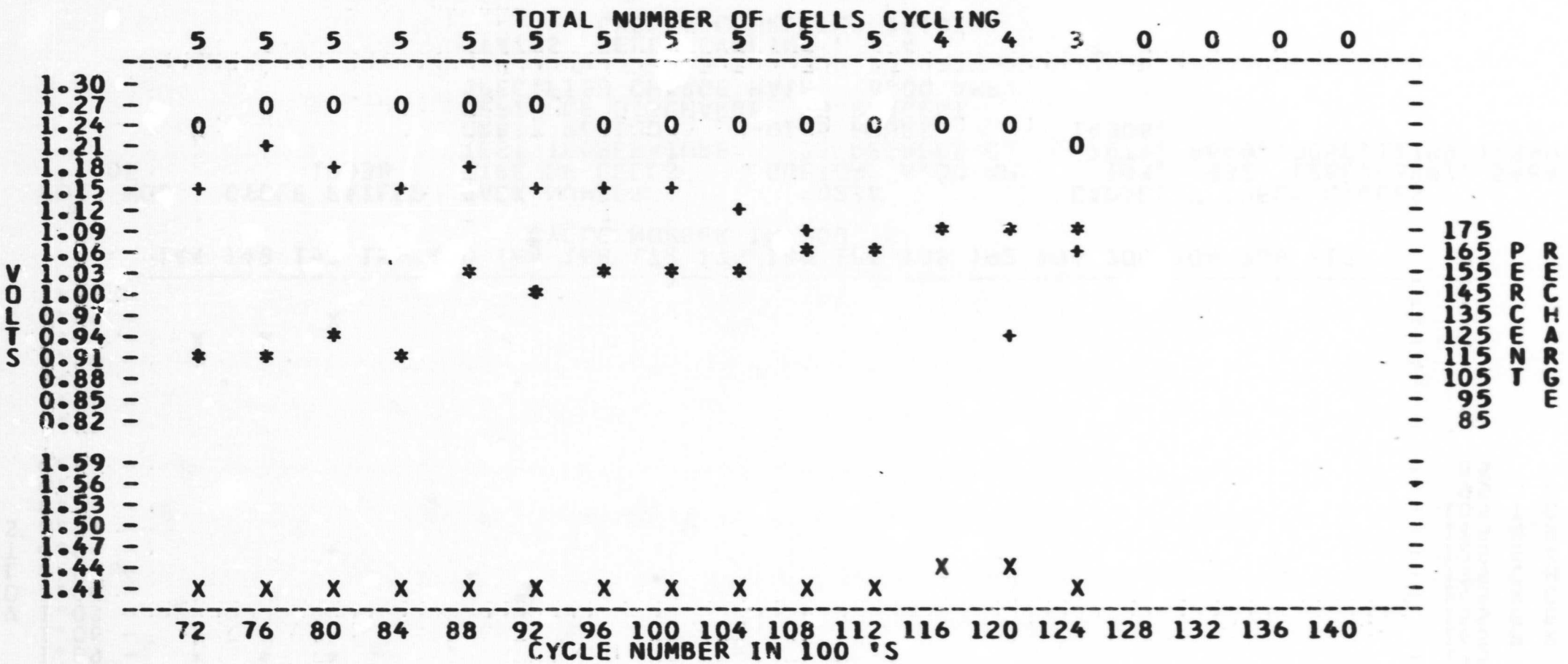
STATUS CELL . CYCLING 4
CYCLES COMPLETED 15132

RESISTOR VALUES AFTER 853 CYCLES: 12, 12, 20, 29, 24 OHMS.

FIGURE 37(B) (CONTD)

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KEY: O - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE




| POS. NO. | CYCLE FAILED | PACK NUMBER | 035A | CAPACITY CHECK CYCLES |
|---|---|---|---|---|
| 04 | 11471 | TYPE OF CELLS | GULTON 6.00 AH | 271, 1111, 2473, 4263, 5521 |
| 05 | 12224 | TEST TEMPERATURE | 40 DEGREES C. | 6995, 8469, 9984, 11295, 12304 |
| | | ORBIT PERIOD | 01.5 HOURS | 0, |
| | | DEPTH OF DISCHARGE | 15 PERCENT | |
| | | SPECIFIED CHARGE RATE | 1.80 AMP. | |
| | | STATUS CELLS CYCLING | 3 | |
| | | CYCLES COMPLETED | 12792 | |

RESISTOR VALUES: 47, 47, 47, 47, 47 OHMS.

FIGURE 37(C)

2. Gulton 6.0 ah (Nickel-Cadmium), Three 5-cell Packs, 1.5-hour Orbit Period:

a. Cell Description: These cells are rectangular in shape. The cell container and the cell cover are made of stainless steel. Both terminals are insulated from the cell cover by ceramic seals and protrude through the cover as solder type terminals. A stainless steel tab, welded to the cover, provides the terminal for the auxiliary electrode. The auxiliary electrode is welded to the inner surface of the cell container. A resistor is mounted externally between the auxiliary electrode and the negative terminal.

b. Test Equipment: The charge current control circuit utilizes the auxiliary electrode voltage from each cell in the pack to reduce the charging rate after the cells have received the predetermined amount of recharge. The circuit is designed to monitor the auxiliary electrode voltage of each cell in a 5-cell pack while being charged. As the auxiliary electrode voltage of any one cell of the pack rises to a preset value, the circuit begins to reduce the charge current. Then as the auxiliary electrode voltages of the cells continue to increase until that of any cell reaches the predetermined maximum (trip voltage), the charge current will be reduced to a preset trickle charge or to zero. The charge and discharge current is supplied by a unit described in section I, paragraph V.B.

c. Test Parameters:

| Pack Number | Test Temperature | Percent Depth of Discharge | Signal Voltage Level (Millivolts) | Resistors On Cells (Ohms) 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|---|
| 48B | * | 40 | 170 | 6.8 | 6.8 | 6.8 | 6.8 | 6.8 |
| 24C | * | 25 | 170 | 6.8 | 6.8 | 6.8 | 6.8 | 6.8 |
| 60B | * | 15 | 170 | 6.8 | 6.8 | 6.8 | 6.8 | 6.8 |

* These cells are in an ambient temperature which varies sinusoidally from 0° to 40° C within a period of 24 hours.

d. Test Results:

(1) Performance on cycling: (Figures 38(A) through 38(C).) Cycling was started in April 1967. The packs have completed from 3305 to 3739 cycles with one cell failure.

(a) From the test data obtained to date the third electrode appears to give a good temperature compensation over the range of temperatures under which these packs were operated.

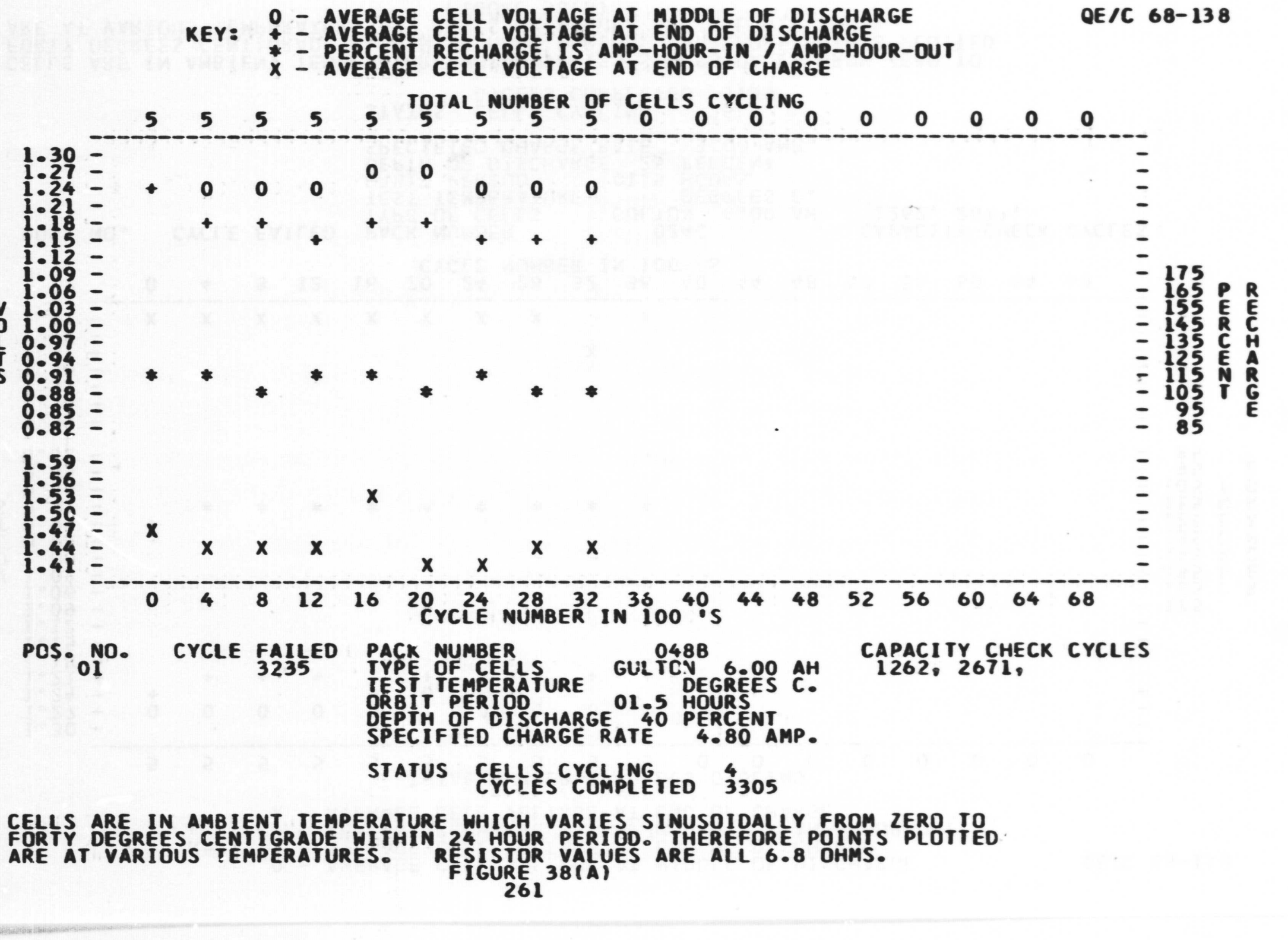
(b) The one cell failure that occurred had the positive and auxiliary electrode shorted together due to insufficient separator between one edge of the positive plates and the auxiliary electrode.

(2) Capacity checks: The ampere-hour capacities on the preconditioning and capacity check cycles consist of a discharge at the cycling discharge rate to 1.0 volt per cell, average, followed by a recharge at the cycling charge rate to the trip voltage level, after which the pack is returned to automatic cycling.

PRECONDITIONING AND CAPACITY CHECKS

| Orbit Period | 1.5-hour | | |
|---|---|---|---|
| Temperature | ** | ** | ** |
| Depth of Discharge | 40% | 25% | 15% |
| Pack Number | 48B | 24C | 60B |
| Preconditioning Capacity | 7.40 | 7.20 | 7.45 |
| 88 Days | 3.68 | 6.90 | 7.02 |
| 176 Days | 2.80 | 6.55 | 7.20 |

** All capacity checks are run at 25° C.




POS. NO. 01 — CYCLE FAILED 3235

PACK NUMBER 048B
TYPE OF CELLS GULTON 6.00 AH
TEST TEMPERATURE DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 40 PERCENT
SPECIFIED CHARGE RATE 4.80 AMP.

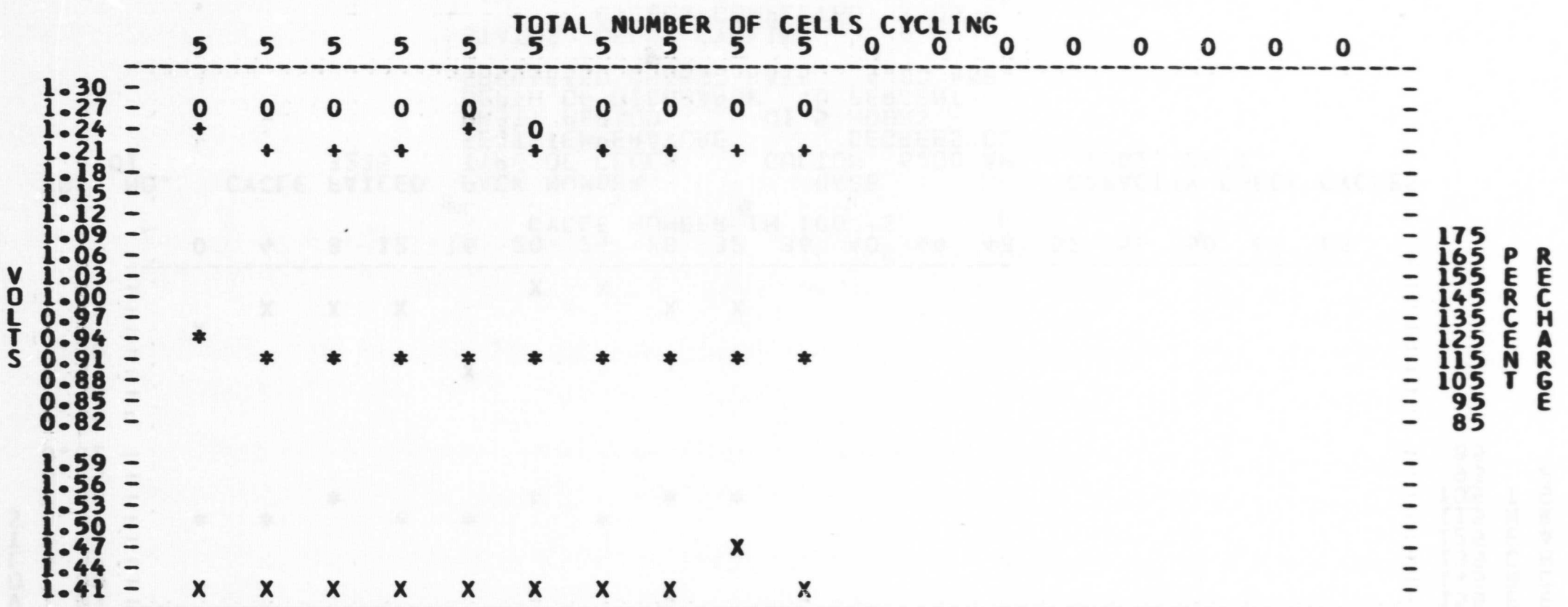
CAPACITY CHECK CYCLES 1262, 2671,

STATUS CELLS CYCLING 4
CYCLES COMPLETED 3305

CELLS ARE IN AMBIENT TEMPERATURE WHICH VARIES SINUSOIDALLY FROM ZERO TO FORTY DEGREES CENTIGRADE WITHIN 24 HOUR PERIOD. THEREFORE POINTS PLOTTED ARE AT VARIOUS TEMPERATURES. RESISTOR VALUES ARE ALL 6.8 OHMS.

FIGURE 38(A)

KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE




POS. NO. CYCLE FAILED

PACK NUMBER 024C
TYPE OF CELLS GULTON 6.00 AH
TEST TEMPERATURE DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 3.00 AMP.

CAPACITY CHECK CYCLES
1262, 2671,

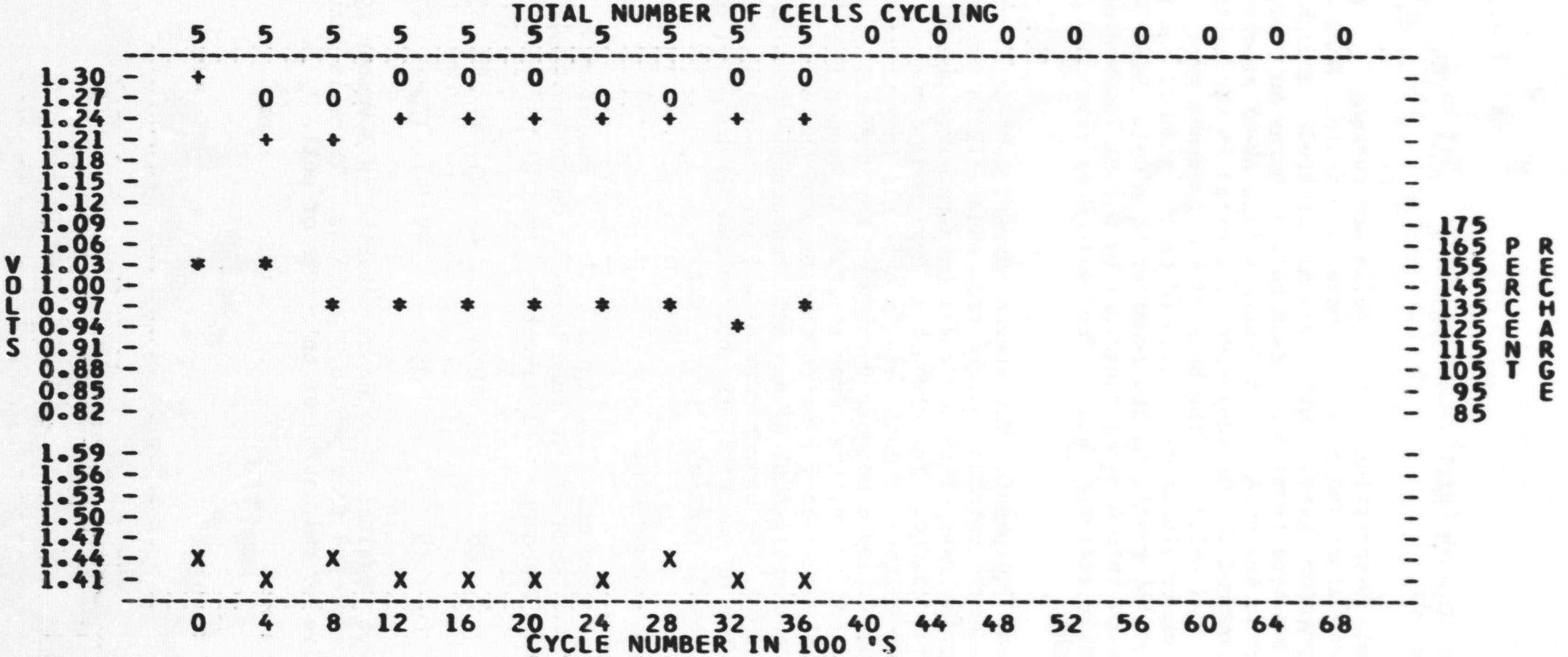
STATUS CELLS CYCLING 5
CYCLES COMPLETED 3739

CELLS ARE IN AMBIENT TEMPERATURE WHICH VARIES SINUSOIDALLY FROM ZERO TO FORTY DEGREES CENTIGRADE WITHIN 24 HOUR PERIOD. THEREFORE POINTS PLOTTED ARE AT VARIOUS TEMPERATURES. RESISTOR VALUES ARE ALL 6.8 OHMS.

FIGURE 38(B)

KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE

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POS. NO. CYCLE FAILED

PACK NUMBER 060B
TYPE OF CELLS GULTON 6.00 AH
TEST TEMPERATURE DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 15 PERCENT
SPECIFIED CHARGE RATE 1.80 AMP.

CAPACITY CHECK CYCLES
1262, 2671,

STATUS CELLS CYCLING 5
CYCLES COMPLETED 3739

CELLS ARE IN AMBIENT TEMPERATURE WHICH VARIES SINUSOIDALLY FROM ZERO TO FORTY DEGREES CENTIGRADE WITHIN 24 HOUR PERIOD. THEREFORE POINTS PLOTTED ARE AT VARIOUS TEMPERATURES. RESISTOR VALUES ARE ALL 6.8 OHMS.

FIGURE 38(C)

3. Gulton 10.0 ah (Nickel-Cadmium), Two 5-cell Packs, 1.5-hour Orbit Period:

a. Cell Description: These cells are rectangular in shape. The cell container and cover are made of plastic. Each cell is fitted with a pressure gage. Both terminals protrude through the cell cover as solder type terminals. Each cell contains an adhydrode as a signal electrode and an American Cyanamid type AB-6X electrode for a scavenger electrode. The adhydrode is located in the center of the plate stack and welded to the base of the pressure gage fitting. The scavenger electrode is located on the side of the plate stack and connected internally to the negative terminal. Each 5-cell pack was epoxy potted into a metal container by Gulton Industries in order to hermetically seal the cells. The cells were developed under Contract NAS 5-10241.

b. Test Equipment: The charge current control circuit utilizes the auxiliary electrode voltage from each cell in the pack to reduce the charging rate after the cells have received the predetermined amount of recharge. The circuit is designed to monitor the auxiliary electrode voltage of each cell in a 5-cell pack while being charged. As the auxiliary electrode voltage of any one cell of the pack rises to a preset value, the circuit begins to reduce the charge current. Then as the auxiliary electrode voltage of the cells continues to increase until that of any cell reaches the predetermined maximum (trip-voltage), the charge current will be reduced to a preset trickel charge or to zero. The charge and discharge current is supplied by a 10-volt regulated power supply.

c. Test Parameters:

| Pack Number | Test Temperature | Percent Depth of Discharge | Signal Voltage Level (Millivolts) | Resistors On Cells (Ohms) 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|---|
| 8B | 25° C | 25 | 250 | 47 | 47 | 47 | 47 | 47 |
| 6B | 40° C | 25 | 250 | 47 | 47 | 47 | 47 | 47 |

d. Test Results: Cycling was started in November 1967. These packs have completed from 535 to 973 cycles. There is insufficient data to give an evaluation of this type of cell.

4. Gulton 12.0 ah (Nickel-Cadmium), Four 5-cell Packs, 1.5-hour Orbit Period:

a. Cell Description: These cells are rectangular in shape. The cell container and cell cover are made of stainless steel. Both terminals are insulated from the cell cover by ceramic seals and protrude through the cover as solder type terminals. A stainless steel tab is welded to the cell cover for the auxiliary electrode terminal. The auxiliary electrode is welded to the inner surface of the cell container. A resistor is mounted externally between the auxiliary electrode and the negative terminal. Recharge percentage may be changed by adjusting the voltage level of the auxiliary electrode detector circuit and/or varying the auxiliary electrode resistance while maintaining a fixed voltage to the detector circuit.

b. Test Equipment: The charge current control circuit utilizes the auxiliary electrode voltage from each cell in the pack to reduce the charging rate after the cells have received the predetermined amount of recharge. The circuit is designed to monitor the auxiliary electrode voltage of each cell in a 5-cell pack while being charged. As the auxiliary electrode voltage of any one cell in the pack rises to a preset value, the total voltage across the pack is reduced to a lower level by shunting current through the control unit. The charge and discharge current is supplied by a unit described in section I, paragraph V.B.

c. Test Parameters:

| Pack Number | Test Temperature | Percent Depth of Discharge | Signal Voltage Level (Millivolts) | Resistors On Cells (Ohms) 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|---|
| 70A | 0° C | 25 | 70 | 6.2 | 6.2 | 6.2 | 6.2 | 6.2 |
| 71B | 0° C | 40 | 70 | 6.2 | 6.2 | 6.2 | 6.2 | 6.2 |
| 11B | 25° C | 40 | 150 | 6.2 | 6.2 | 6.2 | 6.2 | 6.2 |
| 47B | 40° C | 25 | 230 | 6.2 | 6.2 | 6.2 | 6.2 | 6.2 |

d. Test Results:

(1) Performance on cycling: (Figures 39(A) through 39(D).) Cycling was started in October 1966 for one pack; the remaining packs started cycling in January 1967. These packs have completed 4826 to 6457 cycles with no cell failures.

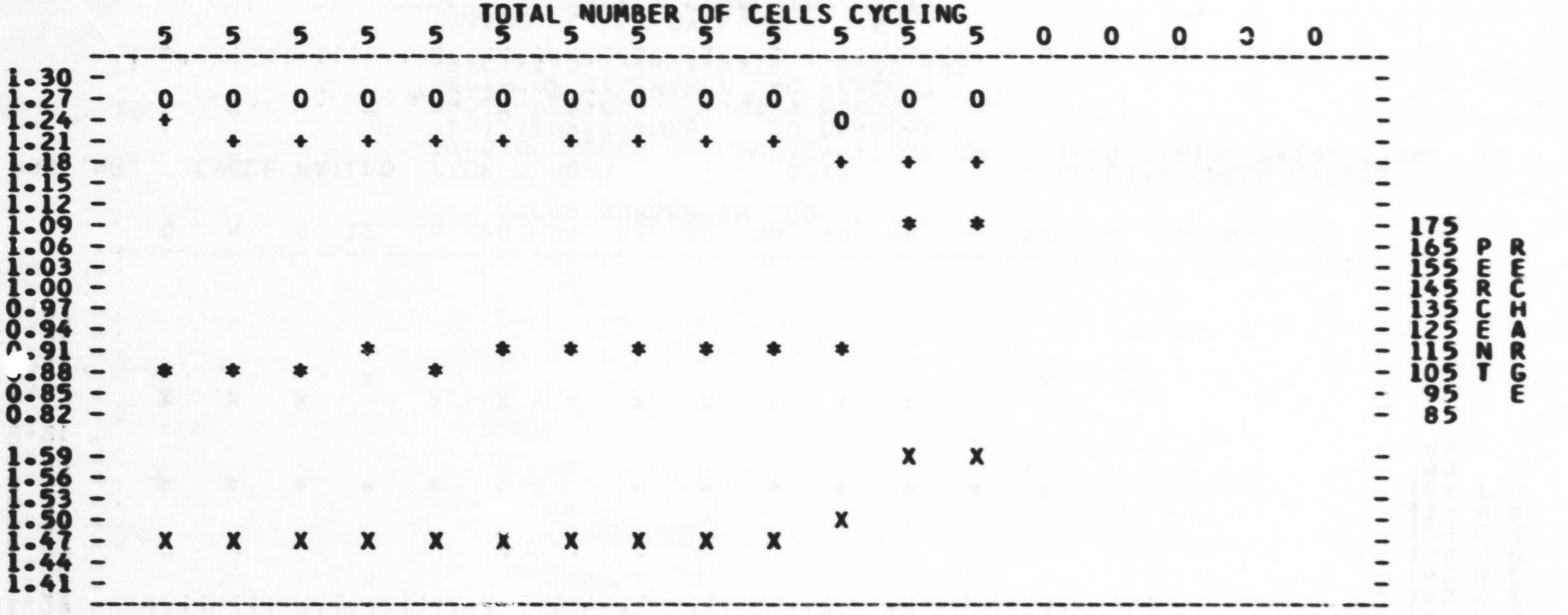
(2) Capacity checks: The ampere-hour capacities on the preconditioning and capacity check cycles are as follows:

PRECONDITIONING AND CAPACITY CHECKS

| Orbit Period | | 1.5-hour | | | |
|---|---|---|---|---|---|
| Temperature | | 0° | 0° | 25° | 40° |
| Depth of Discharge | | 25% | 40% | 40% | 25% |
| Pack Number | | 70A | 71B | 11B | 47B |
| Preconditioning Capacity | | 15.0 | 15.4 | 15.9 | 14.3 |
| 88 Days | Disch #1 | 15.0 | 15.0 | 14.2 | 3.2 |
| | Disch #2 | 14.9 | 15.2 | 14.0 | 3.7 |
| 176 Days | Disch #1 | 15.5 | 14.5 | 7.0 | 3.2 |
| | Disch #2 | 15.4 | 14.5 | 8.1 | 3.5 |
| 264 Days | Disch #1 | 15.1 | 13.0 | 4.9 | 3.0 |
| | Disch #2 | 14.7 | 14.4 | 6.5 | 3.2 |
| 352 Days | Disch #1 | | 12.6 | 5.1 | 9.3 |
| | Disch #2 | | 13.0 | 7.7 | 5.6 |

KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE

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POS. NO. CYCLE FAILED

PACK NUMBER 070A
TYPE OF CELLS GULTON 12.00 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 6.00 AMP.

CAPACITY CHECK CYCLES
1519, 2847, 4258,

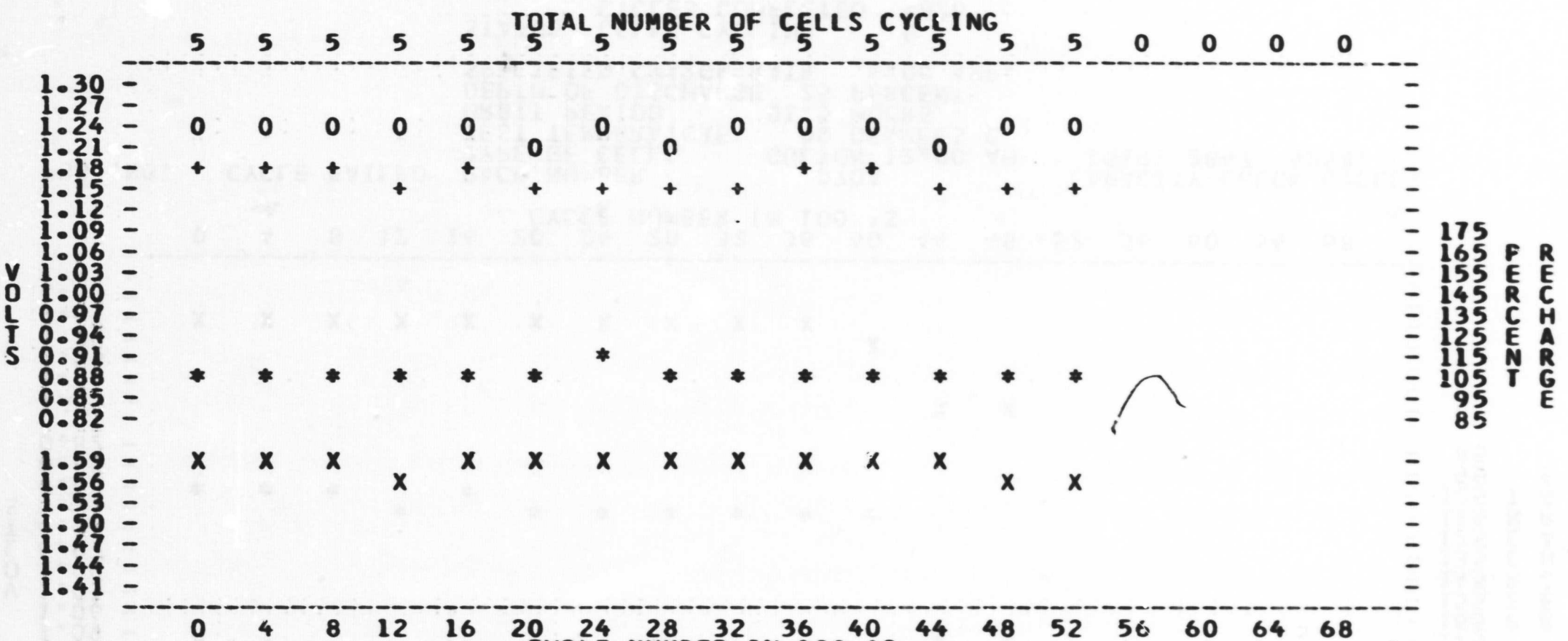
STATUS CELLS CYCLING 5
CYCLES COMPLETED 4826

HIGH PERCENT OF RECHARGE ON CYCLES 4400 AND 4800 DUE TO CHARGE CONTROL UNIT INOPERATIVE
RESISTOR VALUES: 6.2, 6.2, 6.2, 6.2, 6.2 OHMS.

FIGURE 39(A)

KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE

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POS. NO. CYCLE FAILED

PACK NUMBER 071B
TYPE OF CELLS GULTON 12.00 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 40 PERCENT
SPECIFIED CHARGE RATE 6.00 AMP.

CAPACITY CHECK CYCLES
1409, 1612, 3819, 5224,

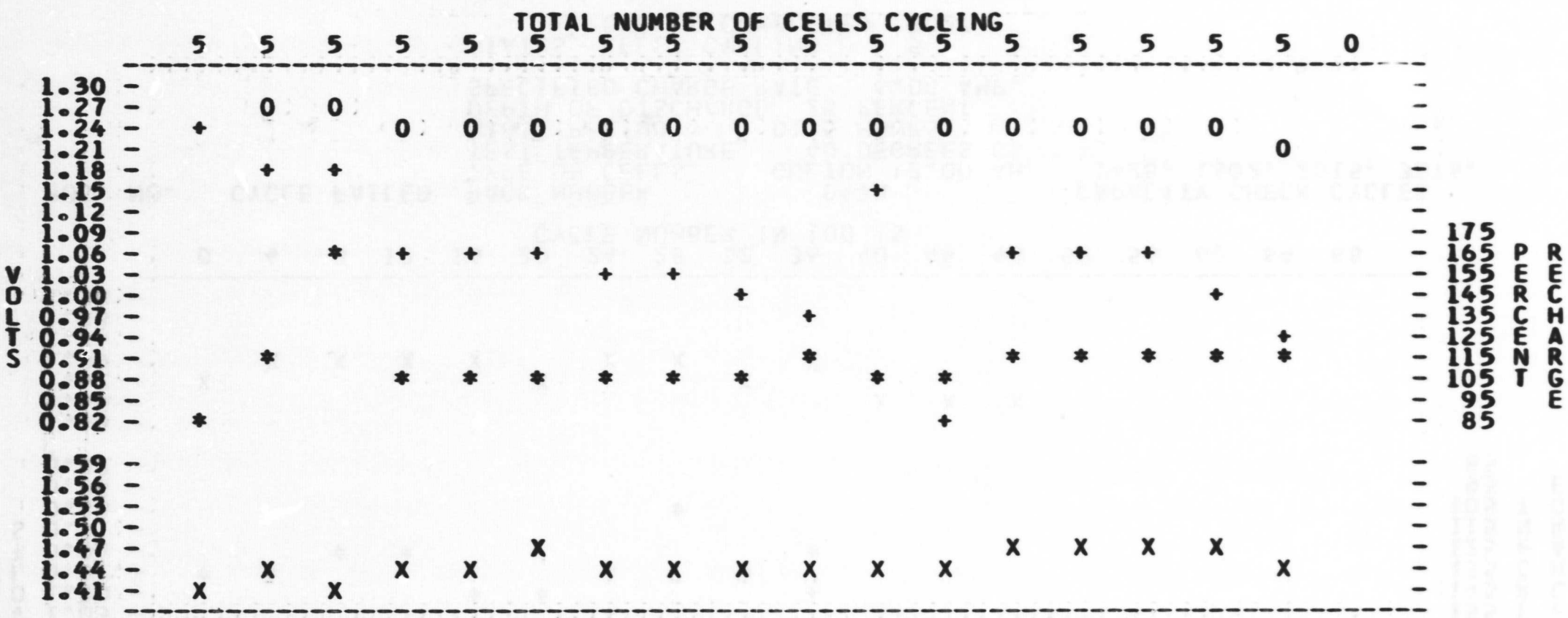
STATUS CELLS CYCLING 5
CYCLES COMPLETED 5273

RESISTOR VALUES: 6.2, 6.2, 6.2, 6.2, 6.2 OHMS.

FIGURE 39(B)

KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE

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POS. NO. CYCLE FAILED

PACK NUMBER 011B
TYPE OF CELLS GULTON 12.00 AH
TEST TEMPERATURE 25 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 40 PERCENT
SPECIFIED CHARGE RATE 6.00 AMP.

CAPACITY CHECK CYCLES
370, 2180, 3906, 4002, 5631
0,

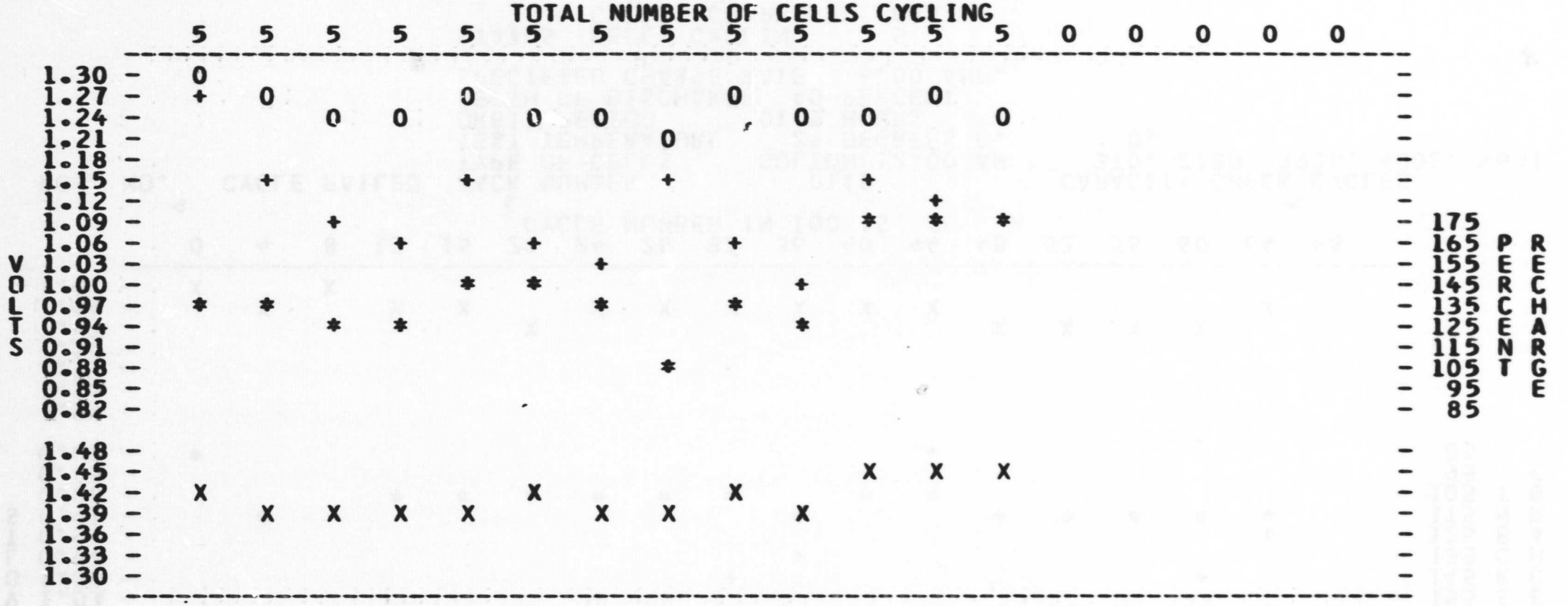
STATUS CELLS CYCLING 5
CYCLES COMPLETED 6457

RESISTOR VALUES: 6.2, 6.2, 6.2, 6.2, 6.2 OHMS.

FIGURE 39(C)

KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHAPGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE

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POS. NO. CYCLE FAILED

PACK NUMBER 047B
TYPE OF CELLS GULTON 12.00 AH
TEST TEMPERATURE 40 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 6.00 AMP.

STATUS CELLS CYCLING 5
CYCLES COMPLETED 5027

CAPACITY CHECK CYCLES
1428, 1602, 2815, 3878,

RESISTOR VALUES: 6.2, 6.2, 6.2, 6.2, 6.2 OHMS

FIGURE 39(D)

5. Gulton 20 ah (Nickel-Cadmium), Three 5-cell Packs, 1.5-hour Orbit Period:

a. Cell Description: These cells are rectangular in shape. The cell container and cell cover are made of stainless steel. Both terminals are insulated from the cover by ceramic seals and protrude through the cover as solder type terminals. Each ceramic seal is set in an expansion joint to remove the stress placed on the seal by the movement of the plates or cell cover. A stainless steel tab is welded to the cover for the auxiliary electrode terminal. The auxiliary electrode is welded to the inner surface of the cell container. A resistor is mounted externally between the auxiliary electrode and negative terminal.

b. Test Equipment: The charge current control circuit utilizes the auxiliary electrode voltage for each cell in the pack to reduce the charging rate after the cells have received a predetermined amount of recharge. The circuit is designed to monitor the auxiliary electrode of each cell in a 5-cell pack while being charged. As the auxiliary electrode voltage of any one cell in the pack rises above a preset value, the charge current is reduced to zero by remotely programming a power supply.

c. Test Parameters:

| Pack Number | Test Temperature | Percent Depth of Discharge | Signal Voltage Level (Millivolts) | Resistors On Cells (Ohms) 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|---|
| 58B | 0° C | 15 | 40 | 6.8 | 6.8 | 6.8 | 6.8 | 6.8 |
| 12C | 25° C | 15 | 200 | 6.8 | 6.8 | 6.8 | 6.8 | 6.8 |
| 36B | 40° C | 15 | 200 | 6.8 | 6.8 | 6.8 | 6.8 | 6.8 |

(1) The following changes in the charge current were made in order to obtain more data on the auxiliary electrode control.

| Pack Number | Cycle | Current | Cycle | Current | Cycle | Current |
|---|---|---|---|---|---|---|
| 58B | 234 | 9.5 Amps | 794 | 19.5 Amps | 1518 | 10 Amps |
| 12C | 85 | 9.6 Amps | 262 | 19.5 Amps | 629 | 10 Amps |
| 36B | 51 | 9.6 Amps | 226 | 19.6 Amps | 698 | 10 Amps |

d. Test Results:

(1) Performance on cycling: (Figures 40(A) through 40(C).) Cycling was started in March 1967. These packs have completed from 3422 to 4399 cycles without any cell failures.

(2) Capacity checks: The ampere-hour capacities on the capacity check cycles are as follows:

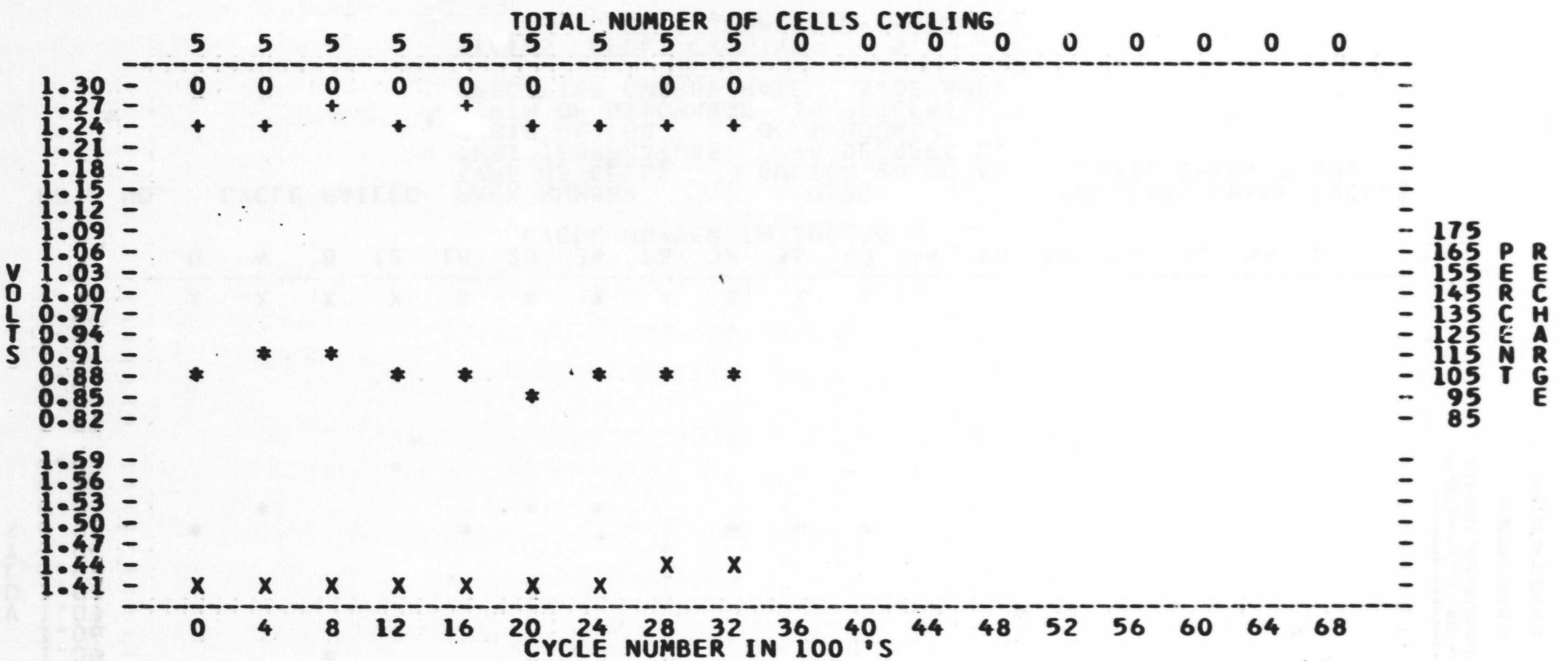
CAPACITY CHECKS

| Orbit Period | 1.5-hour | | |
|---|---|---|---|
| Temperature | 0° | 25° | 40° |
| Depth of Discharge | 15% | 15% | 15% |
| Pack Number | 58B | 12C | 36B |
| 30 Days | ** | 14.7 | ** |
| 88 Days | 20.0 | 20.6 | 10.7 |
| 176 Days | | 20.5 | |

** Capacities were not run due to the changes in charge rate.

KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE

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POS. NO. CYCLE FAILED

PACK NUMBER 058B
TYPE OF CELLS GULTON 20.00 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 15 PERCENT
SPECIFIED CHARGE RATE 5.00 AMP.

CAPACITY CHECK CYCLES
2348,

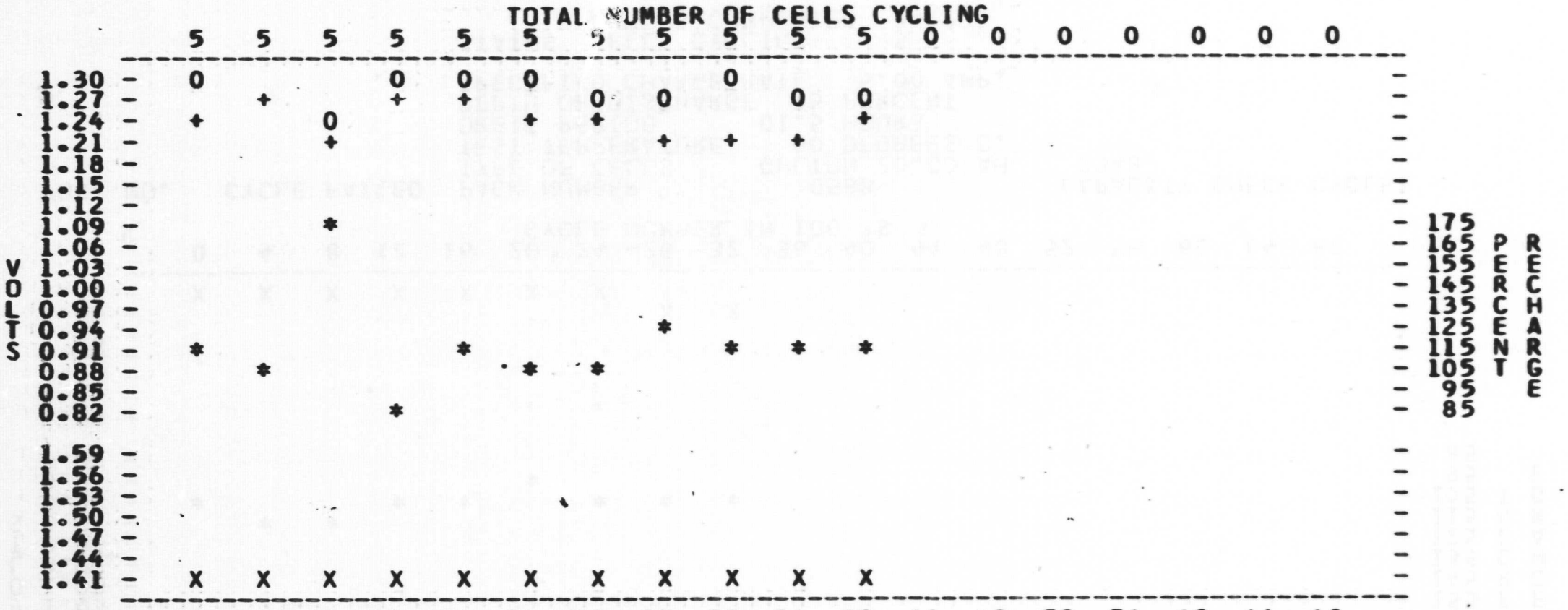
STATUS CELLS CYCLING 5
CYCLES COMPLETED 3422

RESISTOR VALUES:6.8,6.8,6.8,6.8,6.8 OHMS: CYCLE 234: CHARGE CURRENT CHAGED TO 9.5 AMPS. CYCLE 794: CHARGE CURRENT CHANGED TO 19.5 AMPS. CYCLE 1518: CHARGE CURRENT CHANGED TO 10 AMPS.

FIGURE 40(A)

QE/C 68-138

KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE




POS. NO. CYCLE FAILED

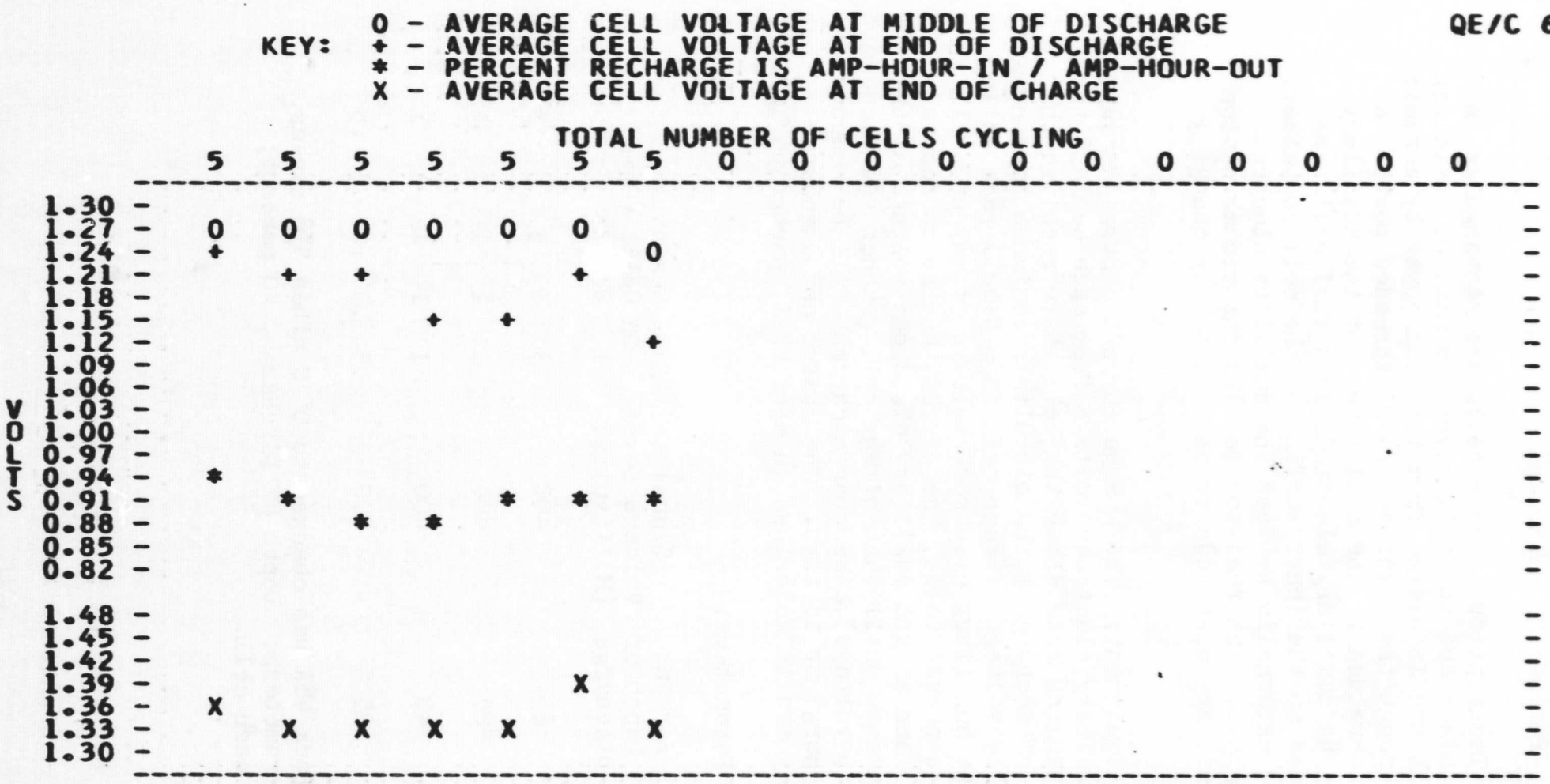
PACK NUMBER 012C
TYPE OF CELLS GULTON 20.00 AH
TEST TEMPERATURE 25 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 15 PERCENT
SPECIFIED CHARGE RATE 5.00 AMP.

CAPACITY CHECK CYCLES
527, 1826, 3249,

STATUS CELLS CYCLING 5
CYCLES COMPLETED 4330

RESISTOR VALUES: 6.8, 6.8, 6.8, 6.8, 6.8 OHMS. CYCLE 85: CHARGE CURRENT TO 9.6 AMPS. CYCE 104: RESISTOR CHANGED TO 13.6 OHMS. CYCLE 262: CHARGE CURRENT TO 19.5 AMPS: CYCLE 629: CHARGE CURRENT TO 10 AMPS.RES. BACK 6.8

FIGURE 40(B)




POS. NO. CYCLE FAILED

PACK NUMBER 036B
TYPE OF CELLS GULTON 20.00 AH
TEST TEMPERATURE 40 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 15 PERCENT
SPECIFIED CHARGE RATE 5.00 AMP.

CAPACITY CHECK CYCLES
1912,

STATUS CELLS CYCLING 5
CYCLES COMPLETED 2740

RESISTOR VALUES: 6.8, 6.8, 6.8, 6.8, 6.8 OHMS: CYCLE 51: CHARGE CURRENT TO 9.6 AMPS. CYCLE 70:RESISTORS CHANGED TO 13.6 OHMS. CYCLE 79: CHANGED RESISTORS TO 6.8 OHMS.CYCLE 226:CURRENT 19.6 AMPS.CYCLE 698:CURRENT TO 10AMP

FIGURE 40(C)

6. General Electric 12.0 ah (Nickel-Cadmium), Four 5-cell Packs, 1.5-hour Orbit Period:

a. Cell Description: These cells are rectangular in shape. The cell container and the cell cover are made of stainless steel. Both terminals are insulated from the cell cover by ceramic seals and protrude through the cover as 1/4-20 threaded posts. A stainless steel tab is welded to the cell cover for the auxiliary electrode terminal. The auxiliary electrode is a fuel cell type electrode and is welded to the inner surface of the cell container. A resistor is mounted externally between the auxiliary electrode and the negative terminal. The resistor permits the recombination capability of the auxiliary electrode to be adjusted by changing the resistance.

b. Test Equipment: The charge current control circuit test utilizes the auxiliary electrode voltage from each cell in the pack to reduce the charging rate after the cells have received the predetermined amount of recharge. The circuit is designed to monitor the auxiliary electrode voltage of each cell in a 5-cell pack while being charged. As the auxiliary electrode voltage of any one cell of the pack rises to a preset value, the circuit begins to reduce the charge current. Then as the auxiliary electrode voltage of the cells continue to increase until that of any cell reaches the predetermined maximum (trip voltage), the charge current will be reduced to a preset trickle charge or to zero. The charge and discharge current is supplied by a unit described in section I, paragraph V.B.

c. Test Parameters:

| Pack Number | Test Temperature | Percent Depth of Discharge | Signal Voltage Level (Millivolts) | Resistors On Cells (Ohms) 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|---|
| 60A | 0° C | 25 | 400 | 3 | 3 | 3 | 3 | 3 |
| 12A | 25° C | 25 | 400 | 1 | 1 | 1 | 1 | 1 |
| 24A | 25° C | 40 | 400 | 1 | 1 | 1 | 1 | 1 |
| 48A | 40° C | 25 | 400 | .5 | .5 | .5 | .5 | .5 |

(1) Pack 48A was changed to 0° C after 528 cycles with the following parameters: Depth of Discharge, 40 percent; Resistors, 3 ohms on each cell.

d. Test Results:

(1) Performance on cycling: Cycling was started in October 1965. These packs have completed from 665 to 5650 cycles with three cell failures.

(a) Pack 12A, at 25° C: The end-of-discharge voltage fell below 1.0 volt per cell, average, on cycle 486. The pack was reconditioned and returned to cycling. At cycle 872 the voltage again dropped below 1.0 volt per cell, average. The pack was again reconditioned. At cycle 1051 the pack again lost capacity and was reconditioned for the third time. Cycling of this pack was discontinued at cycle 1698 because of loss of capacity.

(b) Pack 24A, at 25° C: The end-of-discharge voltage fell below 1.0 volt per cell, average, on cycle 410. The pack was reconditioned and returned to cycling. At cycle 537, the voltage again dropped below 1.0 volt per cell, average. The control unit was then set to charge at 2.5 amperes for the remaining portion of the 60-minute charge period after the trip point had been reached. This overcharge did not improve the capacity of the pack so the test was discontinued on cycle 665.

(c) Pack 48A completed 528 cycles at 40° C at which time the test temperature was reduced to 0° C and the depth of discharge was increased from 25 to 40 percent. Cycling was discontinued after cycle 5110 because the cells would not operate satisfactorily over the entire temperature range of 0° to 40° C. Additional data at 0° C would be of little value in evaluating the cells for space application.

(d) Pack 60A, at 0° C, completed 5650 cycles before it was discontinued for the same reasons given for Pack 48A.

(2) Capacity checks: The ampere-hour capacities on the preconditioning and capacity check cycles are as follows:

## PRECONDITIONING AND CAPACITY CHECKS

| | | | | | |
|---|---|---|---|---|---|
| Orbit Period | | 1.5-hour | | | |
| Temperature | | 0° | 0° | 25° | 25° |
| Depth of Discharge | | 25% | 40% | 25% | 40% |
| Pack Number | | 60A | 48A | 12A | 24A |
| 100 Cycles | Disch #1 | 4.40 | 4.70*** | 10.20 | 8.70 |
| | Disch #2 | 15.00 | 5.30*** | 8.90 | 9.10 |
| 88 Days | Disch #1 | 13.50 | 9.90 | ** | ** |
| | Disch #2 | 15.10 | 15.20 | | |
| 176 Days | Disch #1 | 13.40 | 7.60 | | |
| | Disch #2 | 14.60 | 15.10 | | |
| | | | * | | |
| 264 Days | Disch #1 | | 7.90 | | |
| | Disch #2 | | 11.50 | | |
| | | | * | | |

* Pack Discontinued

** Capacity check at 88 days (1440 cycles) was not run because of earlier losses of capacity.

*** Pack 48A capacity test discharges at this point were at ambient temperature of 40° C.

7. General Electric 12.0 ah (Nickel-Cadmium), Six 5-cell Packs, 1.5-hour Orbit Period:

a. Cell Description: These cells are rectangular in shape. The cell container and cell cover are made of stainless steel. Both terminals are insulated from the cell cover by ceramic seals and protrude through the cover as 1/4-20 threaded posts. A stainless steel tab is welded to the cell cover for the auxiliary electrode terminal. One auxiliary electrode was welded internally to the negative terminal and the other one was welded to the cell container. A resistor is mounted externally between the auxiliary electrode and the negative terminal.

b. Test Equipment: The charge current control circuit utilizes the auxiliary electrode voltage from each cell in the pack to reduce the charging rate after the cells have received the predetermined amount of recharge. The circuit is designed to monitor the auxiliary electrode voltage of each cell in a 5-cell pack while being charged. As the auxiliary electrode voltage of any one cell of the pack rises to a preset value, the total voltage across the pack is reduced to a lower level by shunting current through the control unit. The charge and discharge current is supplied by a unit described in section I, paragraph V.B.

c. Test Parameters:

| Pack Number | Test Temperature | Percent Depth of Discharge | Signal Voltage Level (Millivolts) | Resistors On Cells (Ohms) 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|---|
| 58A | 0° C | 25 | 500 | 6.8 | 6.8 | 6.8 | 6.8 | 6.8 |
| 72A | 0° C | 40 | 500 | 6.8 | 6.8 | 6.8 | 6.8 | 6.8 |
| 12B | 25° C | 25 | 500 | 6.8 | 6.8 | 6.8 | 6.8 | 6.8 |
| 24B | 25° C | 40 | 500 | 6.8 | 6.8 | 6.8 | 6.8 | 6.8 |
| 36A | 40° C | 25 | 500 | 6.8 | 6.8 | 6.8 | 6.8 | 6.8 |
| 34A | 40° C | 40 | 500 | 6.8 | 6.8 | 6.8 | 6.8 | 6.8 |

(1) Upper Voltage Limit: 1.47 ± 0.03 volts per cell, average.

(2) Lower Voltage Limit: 1.40 ± 0.03 volts per cell, average.

d. Test Results:

(1) Performance on cycling: Cycling was started in January 1967. These packs completed from 38 to 404 cycles before they were discontinued. These packs showed large amounts of capacity loss in a very few cycles as reflected in the capacity check data.

(2) Capacity checks: The ampere-hour capacities on the preconditioning and capacity check cycles are as follows:

(a) Pack 58A, at 0° C: Preconditioning capacities were 17.4 ampere-hours on the first discharge and 16.6 ampere-hours on the second discharge. After 133 cycles the pack was again given a capacity check and delivered 16.0 ampere-hours on the first discharge and 15.7 ampere-hours on the second discharge.

(b) Pack 72A, at 0° C: Preconditioning capacities were 17.4 ampere-hours on the first discharge and 16.4 ampere-hours on the second discharge. After 177 cycles the pack was again given a capacity check and delivered 15.6 ampere-hours on the first discharge and 15.6 ampere-hours on the second discharge.

(c) Pack 12B, at 25° C: Preconditioning capacities were 15.9 ampere-hours on the first discharge and 10.5 ampere-hours on the second discharge. After 401 cycles the pack was again given a capacity check and delivered 6.8 ampere-hours on the first discharge and 7.2 ampere-hours on the second discharge.

(d) Pack 24B, at 25° C: Preconditioning capacities were 17.2 ampere-hours on the first discharge and 15.1 ampere-hours on the second discharge. After 38 cycles the pack was again given a capacity check and delivered 4.6 ampere-hours on the first discharge and 6.8 ampere-hours on the second discharge.

(e) Pack 36A, at 40° C: Preconditioning capacities were 12.1 ampere-hours on the first discharge and 6.3 ampere-hours on the second discharge. After 56 cycles the pack was again given a capacity check and delivered 3.5 ampere-hours on the first discharge and 2.6 ampere-hours on the second discharge.

(f) Pack 34A, at 40° C: Preconditioning capacities were 13.0 ampere-hours on the first discharge and 6.7 ampere-hours on the second discharge. After 43 cycles the pack was again given a capacity check and delivered 4.1 ampere-hours on the first discharge and 3.2 ampere-hours on the second discharge.

8. The Electric Storage Battery Company 8.0 ah (Silver-Cadmium), One 5-cell Pack, 8-hour Orbit Period (Pack 1B):

a. Cell Description: These cells are rectangular in shape. The cell jars and cell covers are molded of a plastic material. Each cell is equipped with a pressure gauge, auxiliary electrode, and cellophane bellows. The auxiliary electrode is used for gas recombination only. The plastic bellows is located in the bottom of the cell and is used to control the electrolyte level inside the cell.

b. Test Parameters:

(1) Test Temperature: 25° C.

(2) Depth of Discharge: 25%.

(3) Charge Voltage Limit: 1.51 ± 0.03 volts per cell, average.

(4) Orbit Period: 1-hour discharge, 7-hour charge.

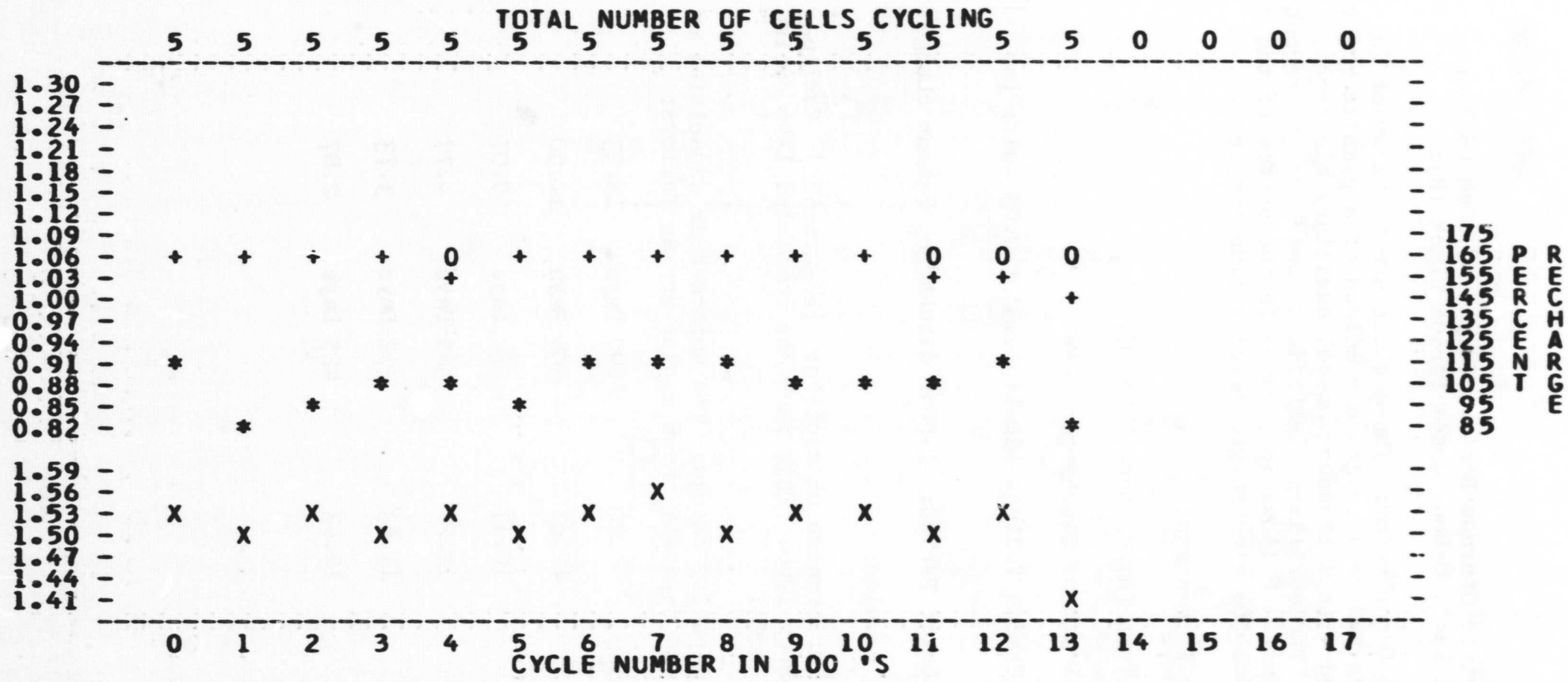
c. Test Results:

(1) Performance on cycling: (Figure 41.) Cycling was started in September 1966. This pack has completed 1346 cycles without any cell failures.

(2) Capacity checks: The ampere-hour capacities on the preconditioning and capacity check cycles are as follows:

| | | | |
|---|---|---|---|
| Preconditioning | 8.20 | 290 Days | 12.23 |
| 80 Days | 12.67 | 304 Days | 11.50 |
| 106 Days | 10.17 | 332 Days | 9.07 |
| 175 Days | 12.27 | 365 Days | 4.77 |
| 211 Days | 11.63 | 392 Days | 3.73 |
| 238 Days | 12.43 | 425 Days | 2.87 |

KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE




POS. NO. CYCLE FAILED

PACK NUMBER 0018
TYPE OF CELLS ESB 8.00 AH
TEST TEMPERATURE 25 DEGREES C.
ORBIT PERIOD 08.0 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 0.50 AMP.

CAPACITY CHECK CYCLES
240, 319, 524, 630, 711
807, 909, 995, 1094, 1175
1274,

STATUS CELLS CYCLING 5
CYCLES COMPLETED 1346

RESISTOR VALUES: 2.2, 2.2, 2.2, 2.2, 2.2 OHMS
CYCLE 742: ALL RESISTORS REMOVED.

FIGURE 41

9. Sonotone 5.0 ah (Nickel-Cadmium), One 5-cell Pack, 1.5-hour Orbit Period (Pack 14D):

a. Cell Description: These cells are rectangular in shape. The cell jars and cell covers are made of a plastic material. Each cell is equipped with an auxiliary electrode which is used for gas recombination. The cells were constructed at the Goddard Space Flight Center from parts supplied by Sonotone. The cells were then individually epoxy potted in order to hermetically seal them.

b. Test Parameters:

(1) Test Temperature: 25° C.

(2) Depth of Discharge: 25%.

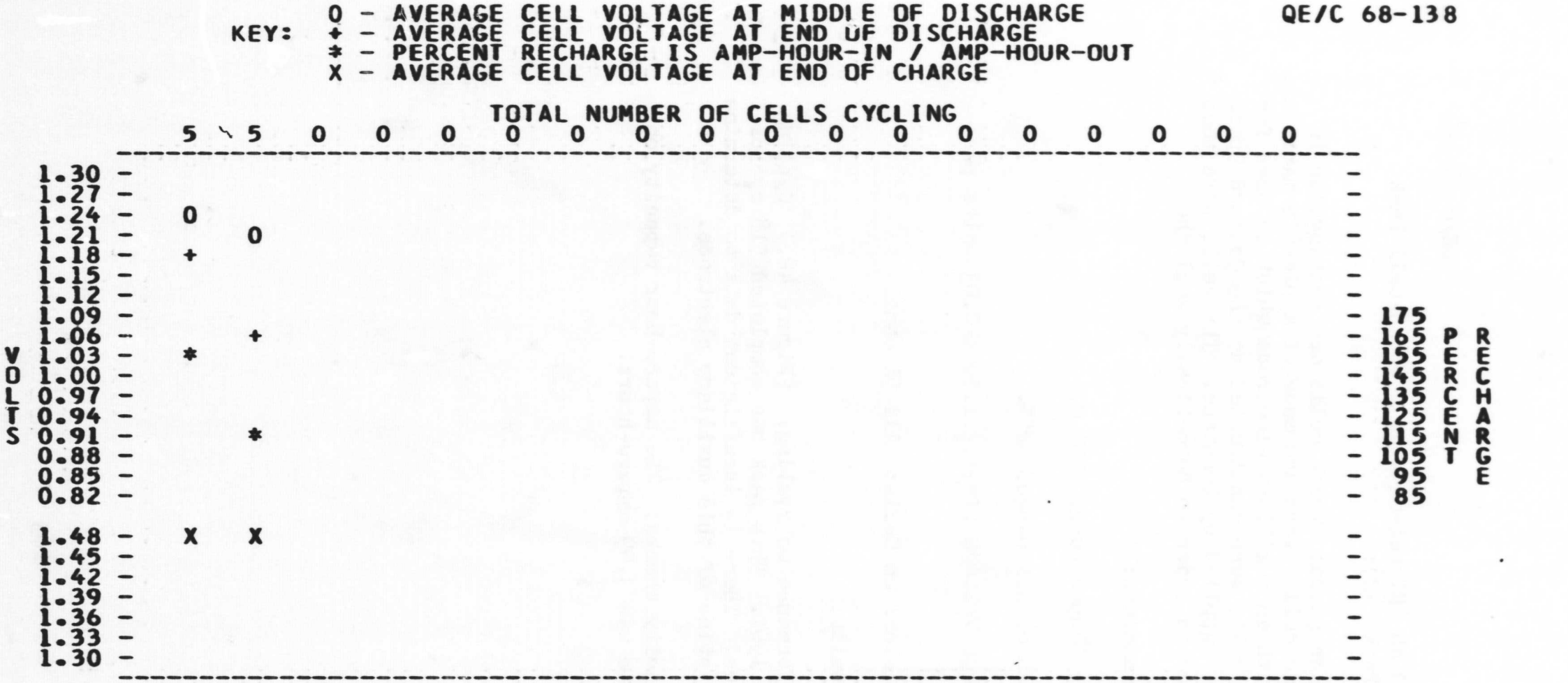
(3) Charge Voltage Limit: 1.50 ± 0.03 volts per cell, average.

(4) Resistors on Cells: All 51 ohms.

c. Test Results:

(1) Performance on cycling: (Figure 42.) Cycling was started in November 1967. This pack has completed 518 cycles without any cell failures. There is insufficient data to determine the operating characteristics of this auxiliary electrode.

(2) Capacity checks: The ampere-hour capacity on the preconditioning cycle was 3.99 ampere-hours.




POS. NO. CYCLE FAILED

PACK NUMBER 014D
TYPE OF CELLS SONOTONE 5.00 AH
TEST TEMPERATURE 25 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 2.50 AMP.

CAPACITY CHECK CYCLES
0,

STATUS CELLS CYCLING 5
CYCLES COMPLETED 518

RESISTOR VALUES 51,51,51,51,51 OHMS

FIGURE 42

10. Yardney 12.0 ah (Silver-Cadmium), Two 5-cell Packs, 24-hour Orbit Period:

a. Cell Description: The cells are rectangular in shape. The cell jars and covers are molded of a plastic material. Each cell contains a fuel cell type auxiliary electrode for gas recombination. The cells were individually epoxy potted and wrapped in fiberglass at Goddard Space Flight Center in order to hermetically seal and strengthen them.

b. Test Parameters:

| Pack Number | Test Temperature | Percent Depth of Discharge | Charge Voltage Limit, Per Cell | Resistors On Cells (Ohms) 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|---|
| 21D | 0° C | 43 | 1.51 ± 0.03 | 1 | 1 | 1 | 1 | 1 |
| 9F | 40° C | 43 | 1.51 ± 0.03 | 1 | 1 | 1 | 1 | 1 |

c. Test Results:

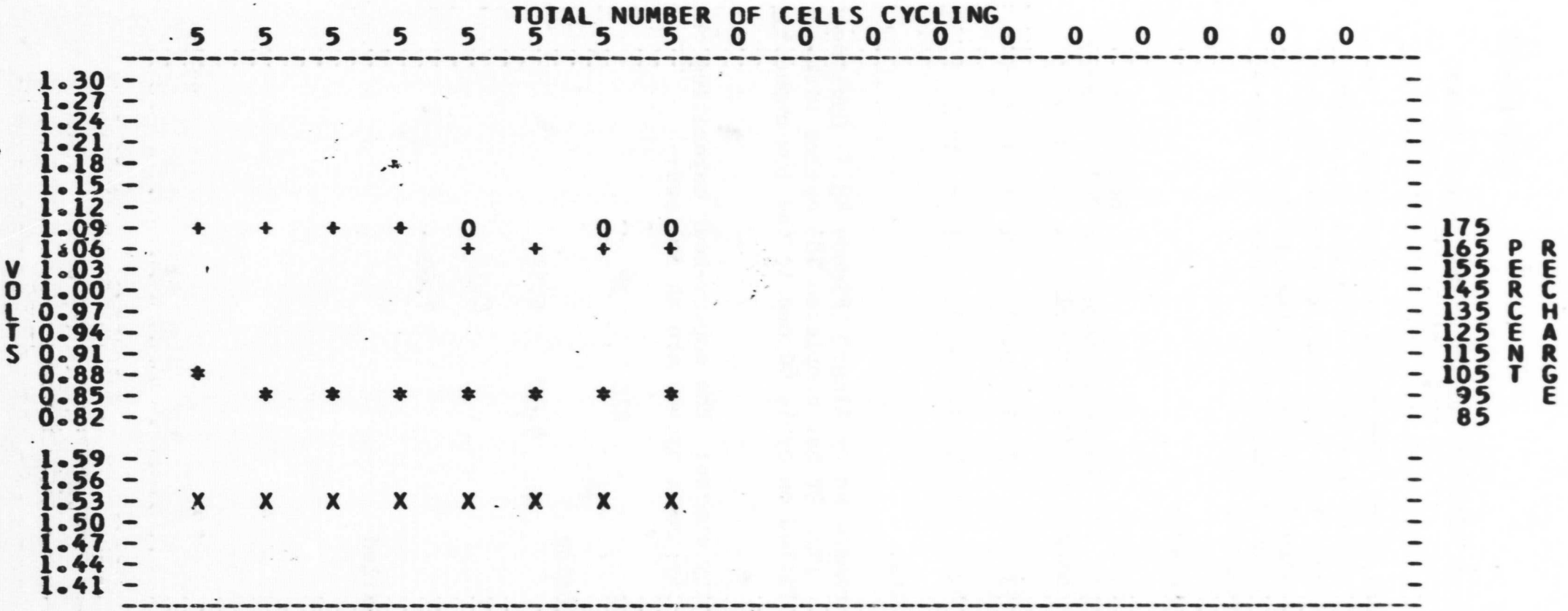
(1) Performance on cycling: (Figure 43.) Cycling was started in June 1967. Pack 9F has completed 185 cycles with no cell failures. Pack 21D failed on cycle 60 due to the low capacity of several cells.

(2) Capacity checks: The ampere-hour capacities on preconditioning and capacity check cycles are as follows:

| Pack Number | 21D | 9F |
|---|---|---|
| Preconditioning Capacity | 4.33 * | 5.53 |
| 100 Days | | 8.33 |
| 200 Days | | 7.60 |

* Pack Failed

KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE




POS. NO. CYCLE FAILED

PACK NUMBER 009F
TYPE OF CELLS YARDNEY 12.00 AH
TEST TEMPERATURE 40 DEGREES C.
ORBIT PERIOD 24.0 HOURS
DEPTH OF DISCHARGE 43 PERCENT
SPECIFIED CHARGE RATE 0.50 AMP.

CAPACITY CHECK CYCLES
110,

STATUS CELLS CYCLING 5
CYCLES COMPLETED 185

CYCLE 26: ELECTROLYTE LEAK
RESISTOR VALUES 1.0,1.0,1.0,1.0,1.0 OHMS

FIGURE 43

C. Stabistor: The stabistor is a semiconductor device that is used to shunt current around a fully charged cell. The stabistor will pass current when the voltage across it has reached the breakdown value. The breakdown voltage depends upon the temperature of the stabistor. At higher temperatures the breakdown voltage is lower than at cold temperatures.

1. Test Equipment: The charge and discharge current and cycling is done with equipment described in section I, paragraph V.B. Across the terminals of each cell are mounted a 5-ampere stabistor to limit the charge current, and an antireversal diode to prevent cell reversal on discharge.

2. Sonotone 5.0 ah (Nickel-Cadmium), Eight 5-cell Packs, 1.5-hour Orbit Period:

a. Cell Description: These are cylindrical cells made of stainless steel. Two stainless steel tabs are welded to the cover for the negative connections. The positive terminal is an extension of the positive plate tab and is insulated from the "negative" cover by a ceramic seal. Two ring indentations, about 1/32 inch deep, located approximately 7/8 inch from either end of the cell can, were crimped after cell assembly to hold the element snugly in the cylindrical can. This cell construction was used for cells in the TIROS satellite.

b. Test Parameters:

(1) Initial Test Parameters:

| Pack Number | Test Temperature | Percent Depth of Discharge |
|---|---|---|
| 75C | -20° C | 25 |
| 89B | -20° C | 40 |
| 92A | 0° C | 25 |
| 122B | 0° C | 40 |
| 73B | 25° C | 25 |
| 87B | 25° C | 40 |
| 99B | 40° C | 25 |
| 112B | 40° C | 40 |

(1) Pack 112B did not cycle satisfactorily at 40 percent depth of discharge so it was reduced to 15 percent, with all other parameters unchanged. All packs are recharged at the c/1 rate (5 amps) because of the 5-ampere stabistor in parallel with each cell.

c. Test Results:

(1) Performance on cycling: (Figure 44.) Cycling was started in August 1965. These packs have completed from 1530 to 8774 cycles with 25 cell failures. The break-down voltage of the stabistors was too high for proper voltage limiting thereby resulting in excessive gassing which broke the ceramic seal. All failed cells had carbonate deposits on the ceramic seals; 11 of which had ceramic shorts. Weak tab to plate welds and migration of negative plate material were also present. Excess scoring was found in 21 of the failed cells.

(2) Capacity checks: The ampere-hour capacities on the preconditioning and capacity check cycles are as follows:

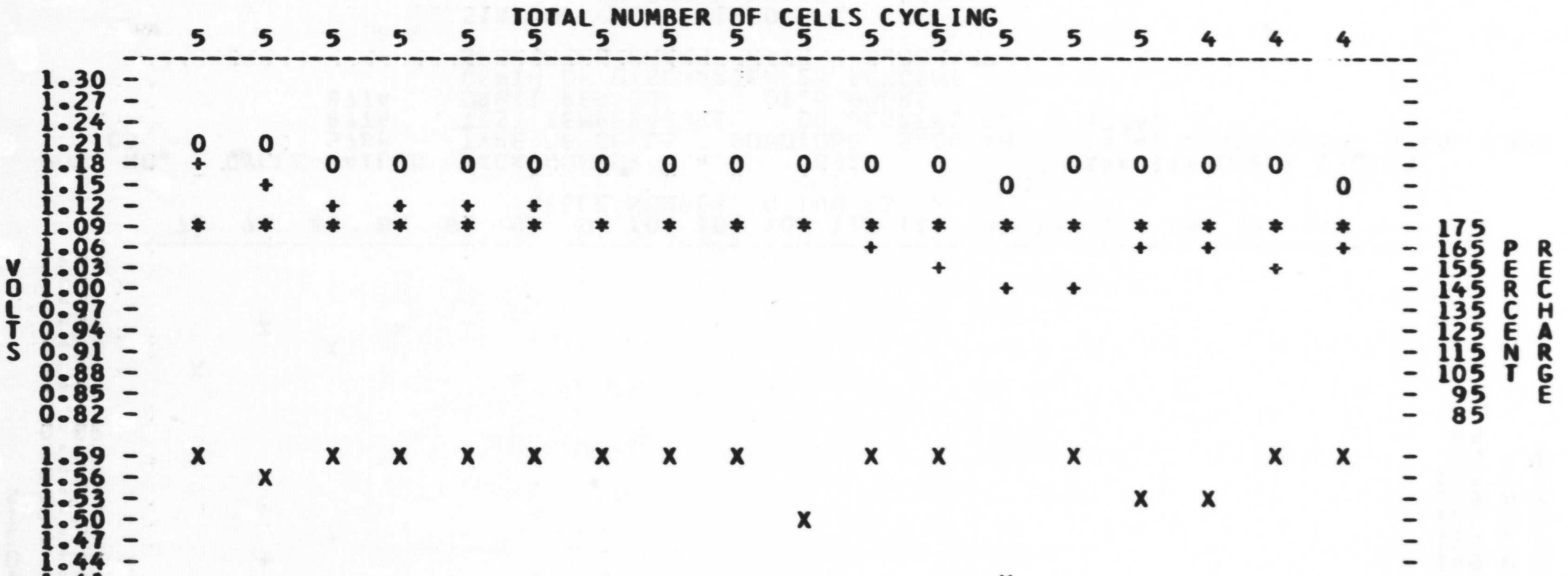
PRECONDITIONING AND CAPACITY CHECKS

| Orbit Period | | 1.5-hour | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Temperature | | -20° | -20° | 0° | 0° | 25° | 25° | 40° | 40° |
| Depth of Discharge | | 25% | 40% | 25% | 40% | 25% | 40% | 25% | 40% |
| Pack Number | | 75C | 89B | 92A | 122B | 73B | 87B | 99B | 112B |
| Preconditioning Capacity | | 4.92 | 4.96 | 3.38 | 4.13 | 5.33 | 5.50 | 4.21 | 3.71 |
| 88 Days | Disch #1 | 1.42 | 3.13 | 2.92 | 2.42 | 1.25 | 1.96 | 1.71 | 0.42 |
| | Disch #2 | 1.21 * | 2.58 * | 2.75 | 2.33 | 2.33 | 3.66 * | 1.88 | 1.04 * |
| 176 Days | Disch #1 | | | 1.75 | 2.63 | 1.17 | | 1.17 | |
| | Disch #2 | | | 1.71 | 1.50 | 1.29 * | | 1.50 | |
| 264 Days | Disch #1 | | | 1.25 | 1.63 | | | 1.13 | |
| | Disch #2 | | | 0.75 | 0.79 | | | 1.17 * | |
| 352 Days | Disch #1 | | | 1.17 | 1.75 | | | | |
| | Disch #2 | | | ** | ** * | | | | |
| 440 Days | Disch #1 | | | 1.46 | | | | | |
| | Disch #2 | | | 1.38 * | | | | | |

* Pack Failed
** Cell failure occurred during capacity check.

KEY: 0 – AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ – AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* – PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X – AVERAGE CELL VOLTAGE AT END OF CHARGE

QE/C 68-138




POS. NO. 05

CYCLE FAILED
5788
8774
8774

PACK NUMBER 092A
TYPE OF CELLS SONOTONE 5.00 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 5.00 AMP.

CAPACITY CHECK CYCLES
1314, 2918, 4357, 5786, 7309
8774,

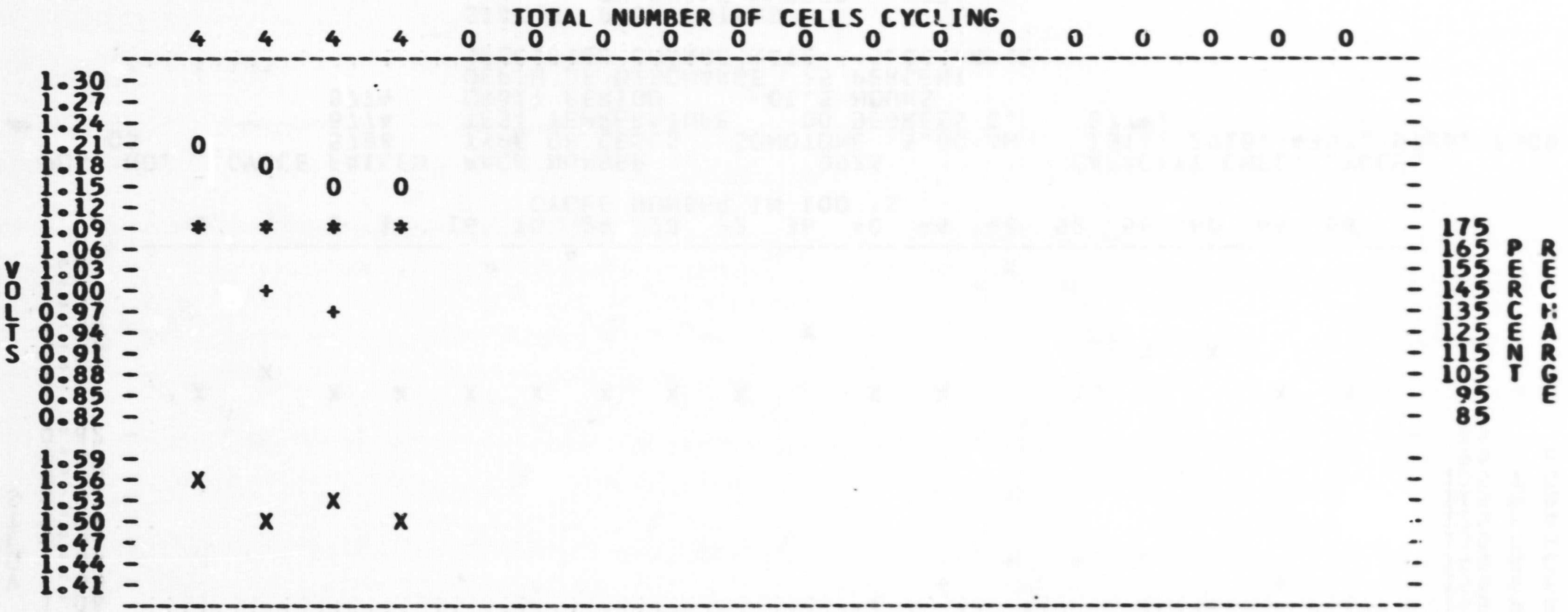
STATUS PACK FAILED
ON CYCLE NUMBER 8774

CHARGE CURRENT CHANGED FROM 2.5 AMPS.TO 5.0 AMPS. AFTER CYCLE 54.

FIGURE 44

KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE

QE/C 68-138




| POS. NO. | CYCLE FAILED | PACK NUMBER | 092A | CAPACITY CHECK CYCLES |
|---|---|---|---|---|
| 05 | 5788 | TYPE OF CELLS | SONOTONE 5.00 AH | 1314, 2918, 4357, 5786, 7309 |
| | 8774 | TEST TEMPERATURE | 00 DEGREES C. | 8774, |
| | 8774 | ORBIT PERIOD | 01.5 HOURS | |
| | | DEPTH OF DISCHARGE | 25 PERCENT | |
| | | SPECIFIED CHARGE RATE | 5.00 AMP. | |

STATUS PACK FAILED
ON CYCLE NUMBER 8774

CHARGE CURRENT CHANGED FROM 2.5 AMPS. TO 5.0 AMPS. AFTER CYCLE 54.

FIGURE 44 (CONTD)

D. Coulometer: The coulometer is a device which measures the amount of electrical charge (coulombs or ampere-hours) passed through it. It accomplishes this by means of an electrochemical reaction which is directly proportional to the product of the magnitude of the current and the time for which it is passed. The coulometer used with nickel-cadmium cells is made from two sets of cadmium hydroxide plates bathed in KOH electrolyte, and constructed in a manner similar to that of a nickel-cadmium cell. Coulometer action is obtained by imbalancing the two sets of plates, so that when one set is completely converted to cadmium by the passage of charge, the other set is totally converted to cadmium hydroxide. This reaction continues at a low voltage on the coulometer until the imbalance is complete. Then the coulometer voltage rises very sharply. The coulometer reaction can take place in either direction, charge or discharge, because the coulometer reaction is completely reversable. Thus it is easy to detect when 100 percent of the discharge has been returned to the cells.

1. Gulton 3.6 ah, One 10-cell Pack, 1.5-hour Orbit Period (Pack 39B):

a. Cell Description: These are cylindrical cells with a folded neoprene seal as described in section II, paragraph I.A.3.a.

b. The coulometer used was built by General Electric with a capacity of 6.0 ampere-hours.

c. Test Equipment: The charge and discharge current for the pack is supplied by a unit which is described in section I, paragraph V.B. The charge is constant current with a preset voltage limit. The voltage limit is set so that a predetermined amount of trickle current is supplied to the pack after the coulometer is fully charged. A diode is mounted across the coulometer to keep the voltage below 1.0 volt.

d. Test Parameters:

(1) Test Temperature: 25° C.

(2) Depth of Discharge: 40%.

e. Test Results:

(1) Performance on cycling: Cycling was started in November 1965. This pack completed 5399 cycles before failing. The coulometer failed after 1868 cycles due to a loss of capacity. The end-of-discharge voltage improved after a new coulometer was placed in the pack. All of the cells in the pack had deposits around the

welded seam between the cover and the can. The positive plate material was very loose.

(2) Capacity checks: The ampere-hour capacities on the preconditioning and capacity check cycles are as follows:

| | |
|---|---|
| Preconditioning | 3.06 |
| 88 Days | 2.07 |
| 176 Days | 2.01 |
| 264 Days | 2.55 |
| 352 Days | 1.71 * |

* Pack Failed

2. Gulton 4.0 ah (Nickel-Cadmium), Seven 5-cell Packs, 1.5-hour Orbit Period:

a. Cell Description: These are rectangular sealed cells of commercial grade. They were epoxy potted into 5-cell packs with a coulometer at the Goddard Space Flight Center in order to hermetically seal the cells and the coulometer before test.

b. Test Parameters:

| Pack Number | Test Temperature | Percent Depth of Discharge |
|---|---|---|
| 40C | -20° C | 25 |
| 52B | 0° C | 25 |
| 26C | 25° C | 15 |
| 14C | 25° C | 25 |
| 37C | 25° C | 40 |
| 38D | 25° C | 60 |
| 39C | 40° C | 25 |

c. Test Results:

(1) Performance on cycling: (Figures 45(A) through 45(E).) Cycling was started on six packs in March 1967. The seventh pack, 40C, failed during preconditioning at -20° C due to high internal pressure which cracked several cells. The six packs have completed from 790 to 4689 cycles with three cell failures. At the request of Goddard Space Flight Center, cycling was stopped upon failure of one cell in a pack.

(2) Capacity checks: The ampere-hour capacities on the preconditioning and capacity check cycles are as follows:

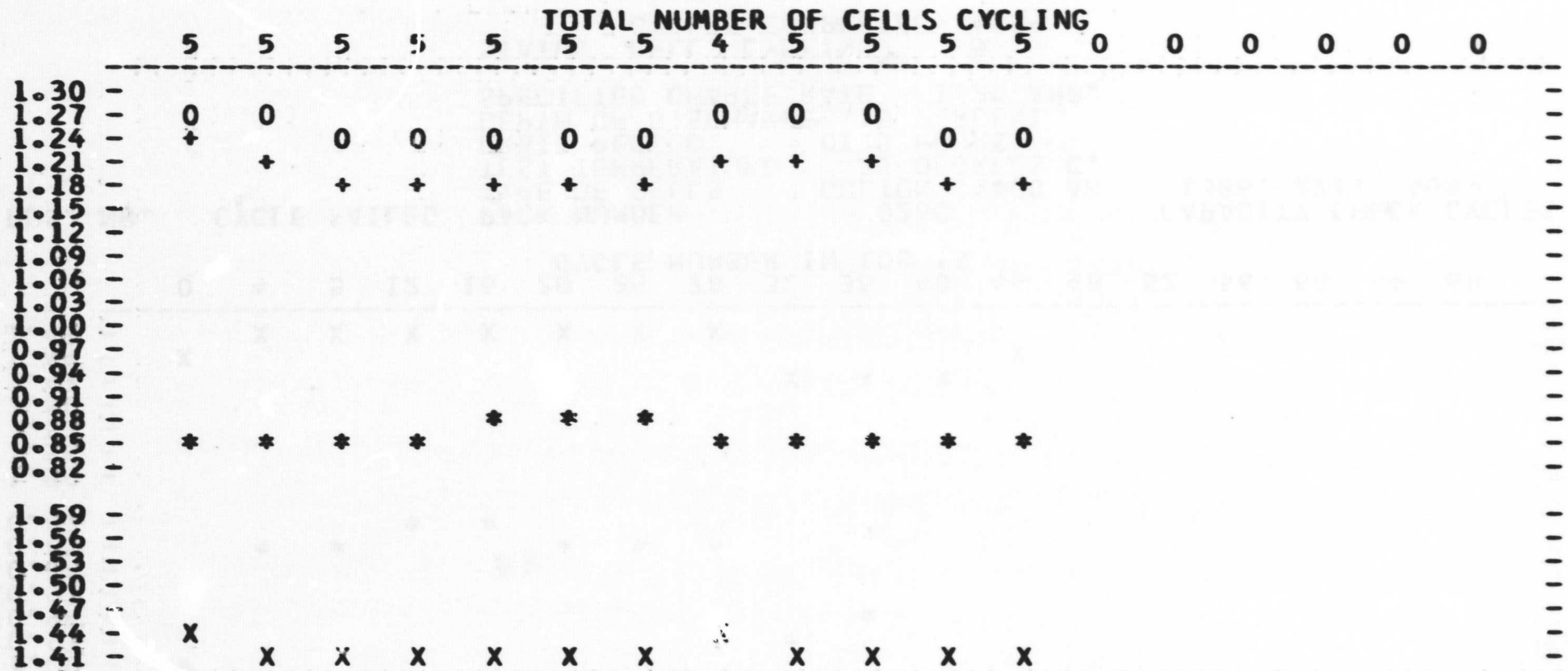
## PRECONDITIONING AND CAPACITY CHECKS

| Orbit Period | | 1.5-hour | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Temperature | | -20° | 0° | 25° | 25° | 25° | 25° | 40° |
| Depth of Discharge | | 25% | 25% | 15% | 25% | 40% | 60% | 25% |
| Pack Number | | 40C | 52B | 26C | 14C | 37C | 38D | 39C |
| Preconditioning Capacity | | ** | 4.43 | 4.67 | 4.23 | 5.03 * | 4.57 | 3.30 |
| 88 Days | Disch #1 | | 3.43 | 3.50 | 3.00 | | 2.00 | 0.97 |
| | Disch #2 | | 4.10 | 3.10 | 3.50 * | | 1.87 * | 1.13 * |
| 176 Days | Disch #1 | | 2.83 | 2.40 | | | | |
| | Disch #2 | | 3.37 | 2.43 | | | | |
| 264 Days | Disch #1 | | 3.00 | 3.70 | | | | |
| | Disch #2 | | 2.33 | 3.37 | | | | |

* Pack Failed
** Pack failure occurred during preconditioning capacity check.

KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE

QE/C 68-138




POS. NO. CYCLE FAILED

PACK NUMBER 0528
TYPE OF CELLS GULTON 4.00 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 2.00 AMP.

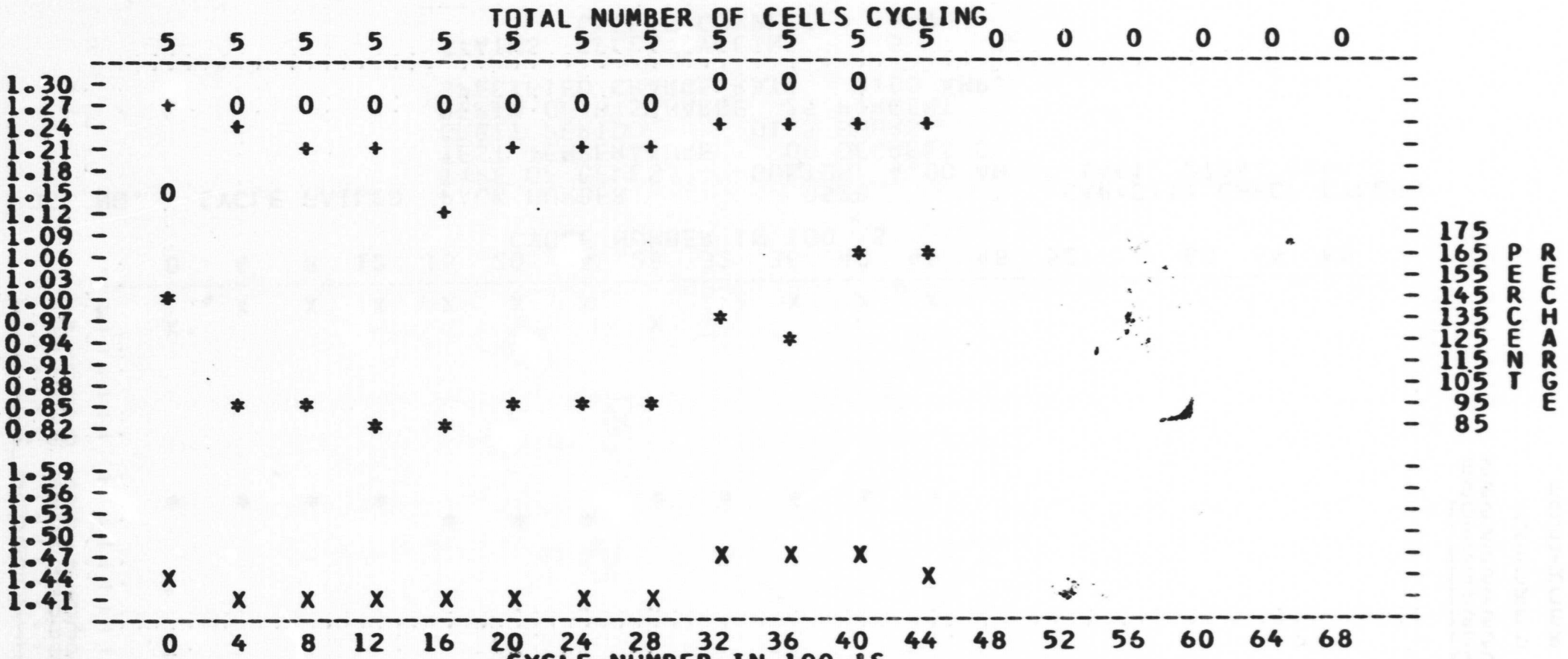
CAPACITY CHECK CYCLES
1441, 2704, 4146,

STATUS CELLS CYCLING 5
CYCLES COMPLETED 4490

FIGURE 45(A)

KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE

QE/C 68-138



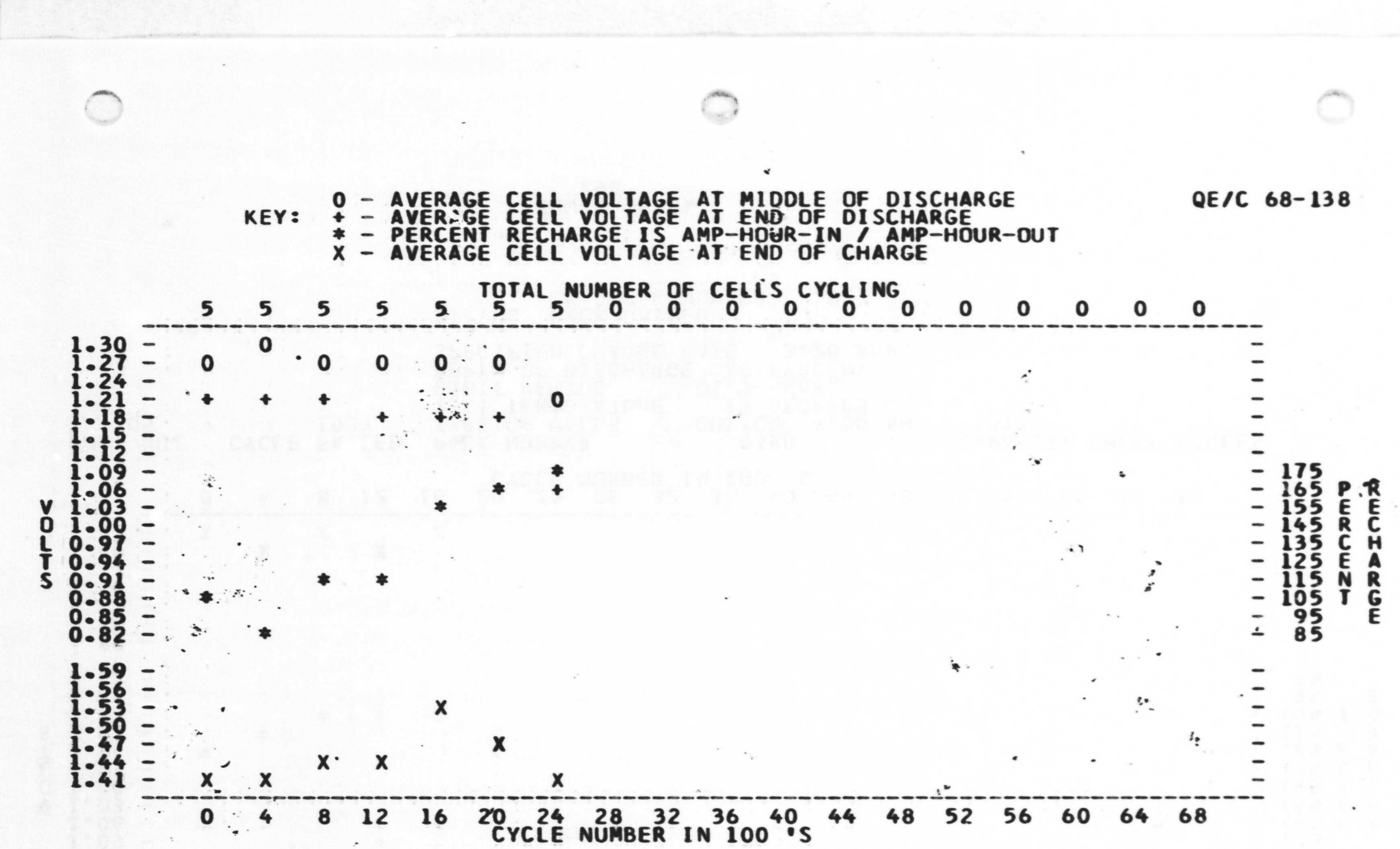

POS. NO. CYCLE FAILED

PACK NUMBER 026C
TYPE OF CELLS GULTON 4.00 AH
TEST TEMPERATURE 25 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 15 PERCENT
SPECIFIED CHARGE RATE 1.20 AMP.

CAPACITY CHECK CYCLES
1386, 2711, 4089,

STATUS CELLS CYCLING 5
CYCLES COMPLETED 4689

FIGURE 45(B)

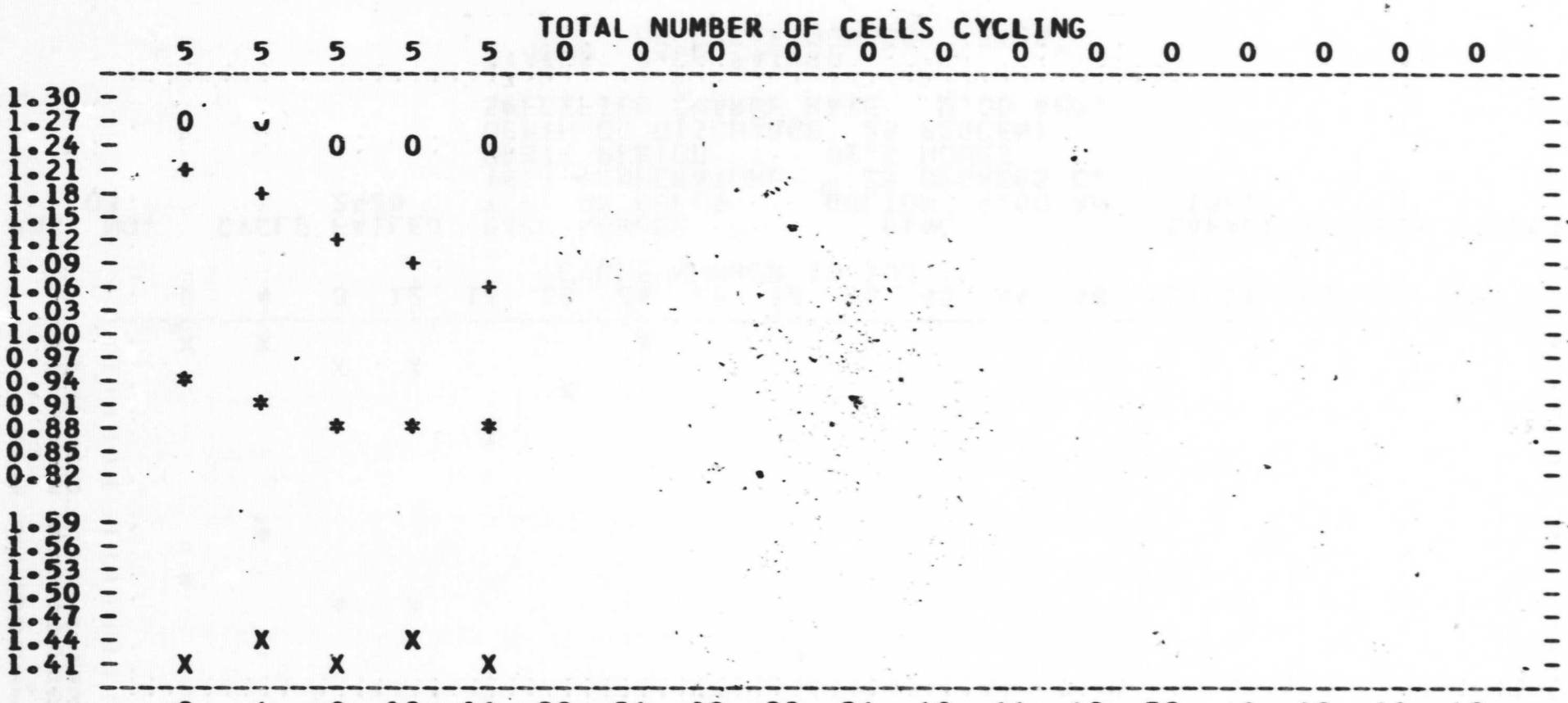



| POS. NO. | CYCLE FAILED | | PACK NUMBER | 014C | CAPACITY CHECK CYCLES |
|---|---|---|---|---|---|
| 03 | 2428 | | TYPE OF CELLS | GULTON 4.00 AH | 1381, |
| | | | TEST TEMPERATURE | 25 DEGREES C. | |
| | | | ORBIT PERIOD | 01.5 HOURS | |
| | | | DEPTH OF DISCHARGE | 25 PERCENT | |
| | | | SPECIFIED CHARGE RATE | 2.00 AMP. | |
| | | STATUS | PACK FAILED ON CYCLE NUMBER | 2428 | |

FIGURE 45(C)

KEY: 0 – AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ – AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* – PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X – AVERAGE CELL VOLTAGE AT END OF CHARGE

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POS. NO. 05

CYCLE FAILED 1927

PACK NUMBER 038D
TYPE OF CELLS GULTON 4.00 AH
TEST TEMPERATURE 25 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 60 PERCENT
SPECIFIED CHARGE RATE 3.20 AMP.

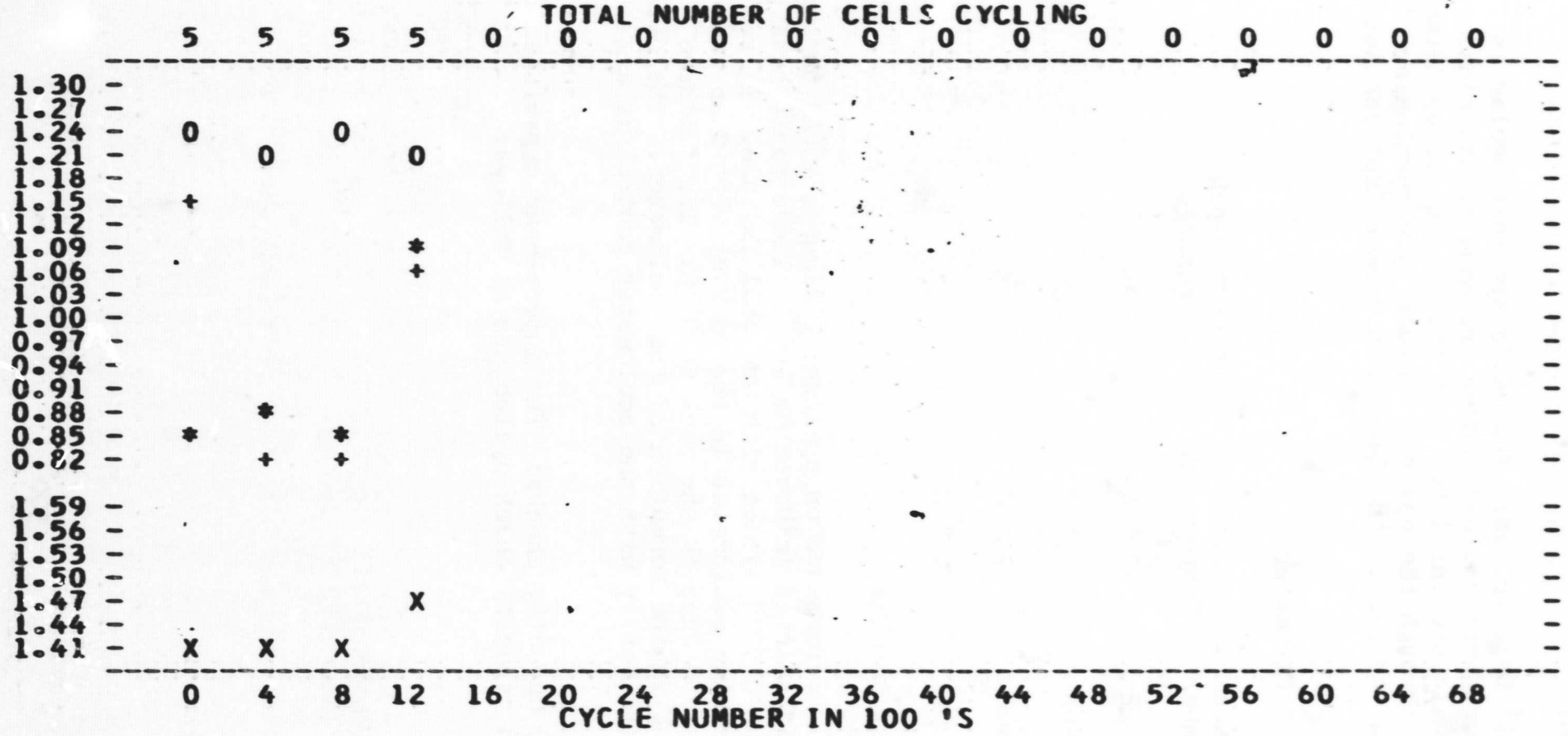
CAPACITY CHECK CYCLES
1318,

STATUS PACK FAILED
ON CYCLE NUMBER 1927

FIGURE 45(D)

KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE

QE/C 68-138




| POS. NO. | CYCLE FAILED | | |
|---|---|---|---|
| 05 | 1508 | | |

PACK NUMBER 039C
TYPE OF CELLS GULTON 4.00 AH
TEST TEMPERATURE 40 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 2.00 AMP.

CAPACITY CHECK CYCLES
1319,

STATUS PACK FAILED
ON CYCLE NUMBER 1508

FIGURE 45(E)

3. Gulton 6.0 Ah (Nickel-Cadmium), Four 5-cell Packs, 3-hour Orbit Period:

a. Cell Description: The cells are rectangular in shape. The cell container and cell cover are made of stainless steel. Both terminals are insulated from the cell cover by ceramic seals and protrude through the cover as solder type terminals. The cells were designed for use in the Radio Astronomer Explorer satellite.

b. Test Parameters:

| Pack Number | Test Temperature | Percent Depth of Discharge |
|---|---|---|
| 41B | -20° C | 25 |
| 66B | 0° C | 25 |
| 18C | 25° C | 25 |
| 29B | 40° C | 25 |

c. Test Results:

(1) Performance on cycling: (Figures 46(A) through 46(D).) Cycling was started in November 1966. These packs have completed from 2645 to 3078 cycles with one cell failure. It was necessary to replace the coulometer in the pack at -20° C on four different occasions and once in the pack at 0° C. The failures were due to problems in the formation of the coulometer. The cells have operated satisfactorily with the coulometer control at all temperatures.

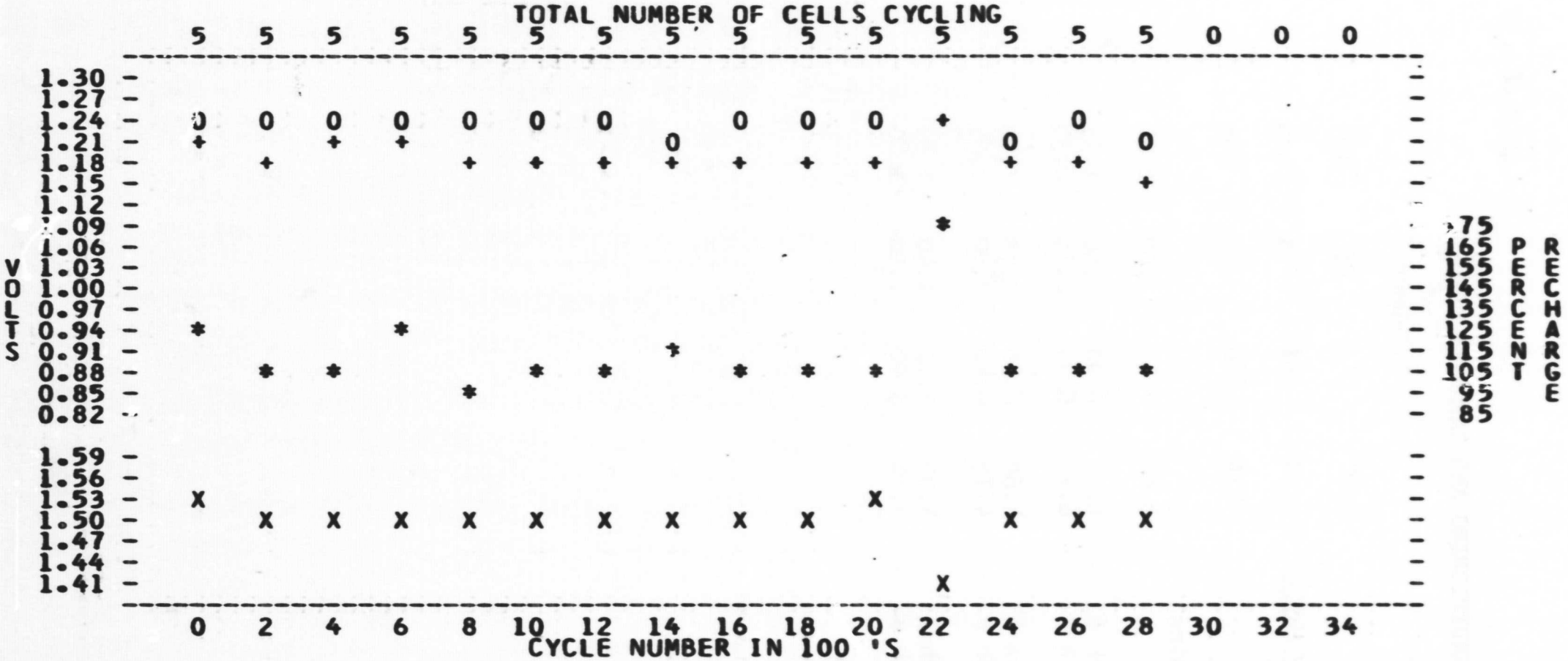
(2) Capacity checks: The ampere-hour capacities on preconditioning and capacity check cycles are as follows:

## PRECONDITIONING AND CAPACITY CHECKS

| | | | | | |
|---|---|---|---|---|---|
| Orbit Period | | | 1.5-hour | | |
| Temperature | | -20° | 0° | 25' | 40° |
| Depth of Discharge | | 25% | 25% | 25% | 25% |
| Pack Number | | 41B | 66B | 18C | 29B |
| Preconditioning Capacity | | 6.60 | 7.15 | 7.00 | 6.25 |
| 88 Days | Disch #1 | 5.75 | 6.90 | 1.90 | 1.35 |
| | Disch #2 | 6.45 | 6.90 | 2.75 | 2.35 |
| 176 Days | Disch #1 | 4.60 | 6.80 | 1.75 | 1.40 |
| | Disch #2 | 4.75 | 6.40 | 1.80 | 1.65 |
| 264 Days | Disch #1 | 4.05 | 5.70 | 1.40 | 1.55 |
| | Disch #2 | 4.50 | 5.70 | 1.50 | 1.80 |

KEY: 0 – AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ – AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* – PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X – AVERAGE CELL VOLTAGE AT END OF CHARGE

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POS. NO. CYCLE FAILED

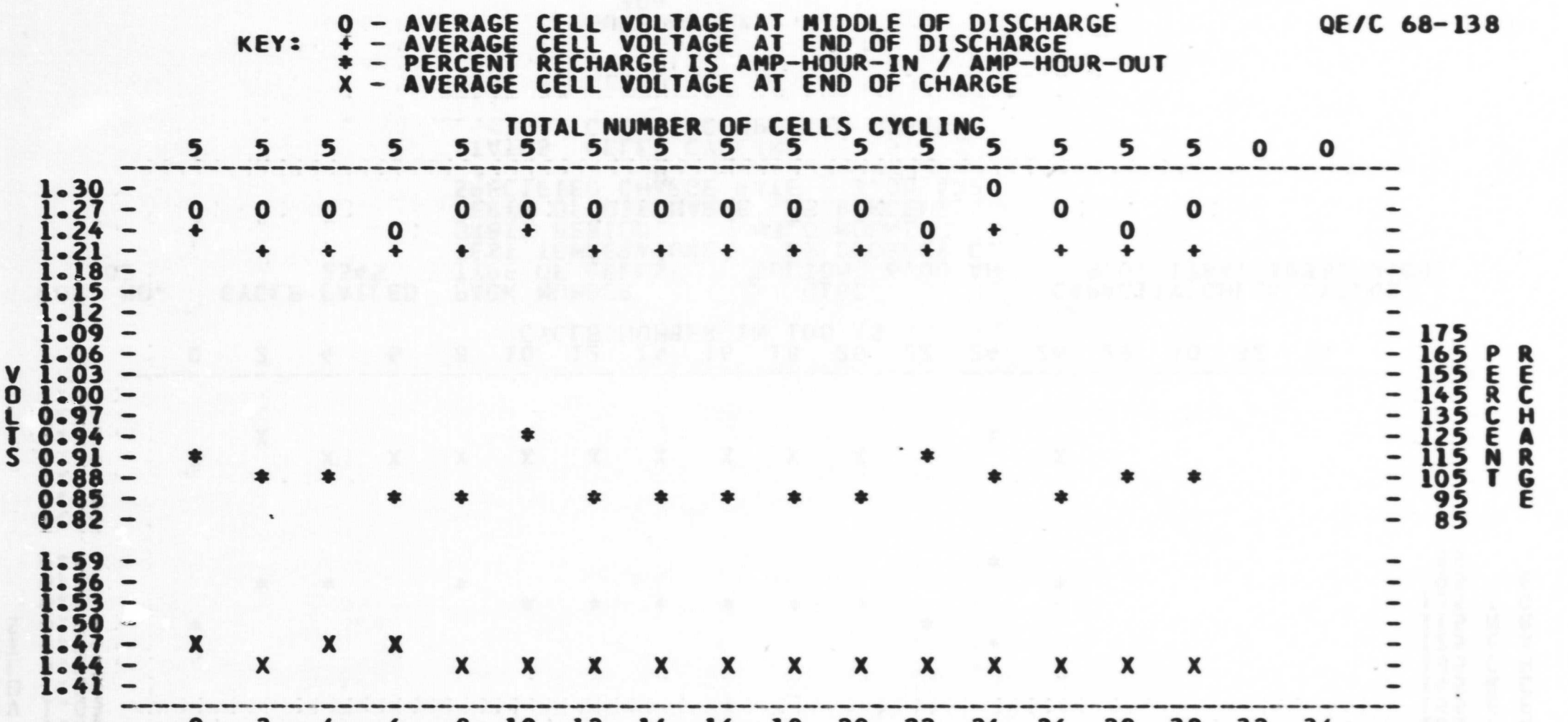
PACK NUMBER 041B
TYPE OF CELLS GULTON 6.00 AH
TEST TEMPERATURE -20 DEGREES C.
ORBIT PERIOD 03.0 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 3.00 AMP.

CAPACITY CHECK CYCLES
889, 1706, 2244,

STATUS CELLS CYCLING 5
CYCLES COMPLETED 2825

CYCLE 730:COULOMETER FAILED. CYCLE 730:NEW COULOMETER ADDED CYCLE 923:
COULOMETER FAILED. CYCLE 923: NEW COULOMETER ADDED. CYCLE 1706:COULOMETER
FAILED:NEW COULOMETER ADDED.CYCLE 2235:COULOMETER FAILED:NEW COULOMETER

FIGURE 46(A)




POS. NO. CYCLE FAILED

PACK NUMBER 066B
TYPE OF CELLS GULTON 6.00 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 03.0 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 3.00 AMP.

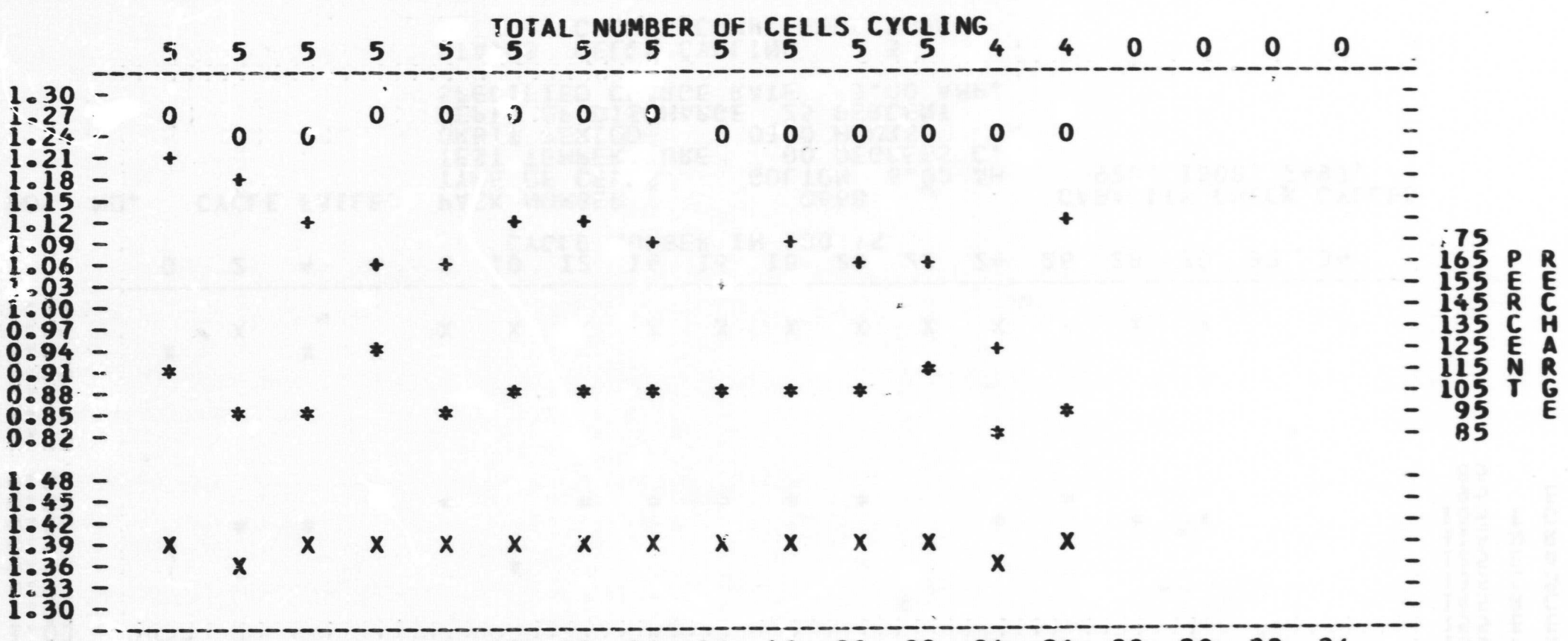
CAPACITY CHECK CYCLES
920, 1808, 2497,

STATUS CELLS CYCLING 5
CYCLES COMPLETED 3078

CYCLE 729: COULOMETER FAILED: CYCLE 776: PUT NEW COULOMETER IN

FIGURE 46(B)

KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE




POS. NO. 02 — CYCLE FAILED 2345

PACK NUMBER 018C
TYPE OF CELLS GULTON 6.00 AH
TEST TEMPERATURE 25 DEGREES C.
ORBIT PERIOD 03.0 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 3.00 AMP.

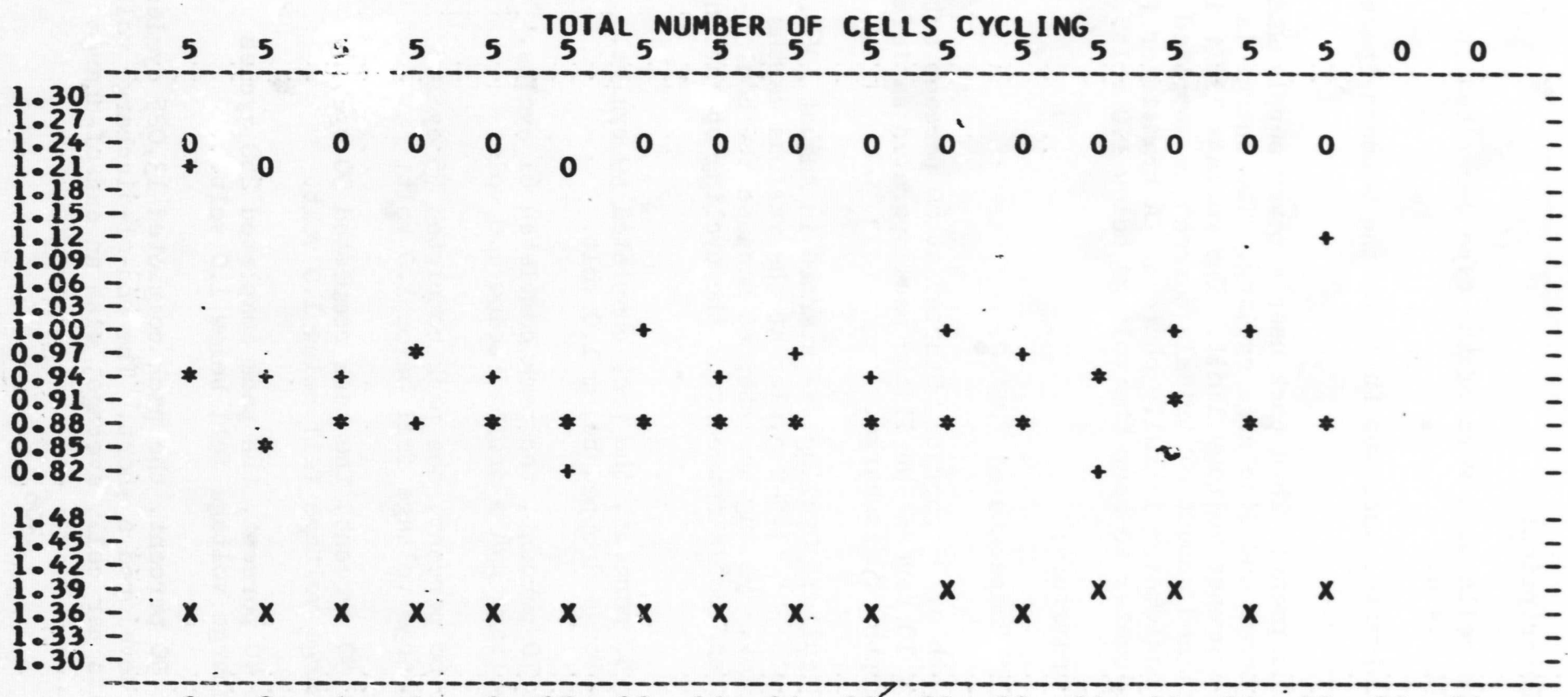
STATUS CELLS CYCLING 5
CYCLES COMPLETED 2645

CAPACITY CHECK CYCLES
920, 1784, 1833, 2400,

FIGURE 46(C)

KEY: 0 - AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ - AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* - PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X - AVERAGE CELL VOLTAGE AT END OF CHARGE

QE/C 68-138




POS. NO. CYCLE FAILED

PACK NUMBER 029B
TYPE OF CELLS GULTON 6.00 AH
TEST TEMPERATURE 40 DEGREES C.
ORBIT PERIOD 03.0 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 3.00 AMP.

CAPACITY CHECK CYCLES
894, 1721, 2393,

STATUS CELLS CYCLING 5
CYCLES COMPLETED 3014

FIGURE 46(D)

4. Sonotone 5.0 ah, One 5-cell Pack, 1.5-hour Oribt Period:

a. Cell Description:

(1) The cells used were of the type described in section I, paragraph II.A.4.a.

b. The coulometer used was built by the Goddard Space Flight Center.

c. Test Equipment: This pack uses a power supply and electronic timer for charge and discharge cycling. The charge is constant current with a preset voltage limit. The voltage limit is set so that a predetermined amount of trickle current is supplied to the pack after the coulometer is fully charged. A transistor is mounted across the coulometer to keep the voltage below 1.0 volt.

d. Test Parameters:

(1) Test Temperature: 25° C.

(2) Depth of Discharge: Started at 80 percent but was lowered by steps of 10 percent until the pack operated satisfactorily at 30 percent depth of discharge.

e. Test Results: Cycling was started in August 1964. Upon completion of a total of 13,540 cycles at the various depths of discharge listed below, cycling was stopped because the coulometer developed a short and could not control the cycling operation any longer.

(1) At 80 percent, the pack completed 59 cycles. The end-of-discharge voltage dropped below 1.0 volt.

(2) At 70 percent, the pack completed 61 cycles. The end-of-discharge voltage again dropped below 1.0 volt.

(3) At 60 percent, the pack completed 55 cycles before the end-of-discharge voltage fell below 1.0 volt.

(4) At 50 percent, the pack completed 90 cycles before the end-of-dicharge voltage fell below 1.0 volt.

(5) At 40 percent, the pack completed 250 cycles before the end-of-discharge voltage fell below 1.0 volt.

(6) At 30 percent, the pack completed 13,025 cycles before the coulometer developed a short. The end-of-discharge voltage was about 1.07 volts per cell, average, with an end-of-charge

voltage of 1.42 volts per cell, average, over the entire cycle life. The percent of recharge, as controlled by the coulometer, ranged from 104 to 111 percent with an average value of 106 percent.

E. Sherfey Upside-Down Cycling: This type of cycling starts with the cells in a completely discharged condition. Each cycle consists of a charge of 60 percent followed by a discharge of 40 percent of the cell's rated capacity. Upon completion of each fifth cycle, the cells are discharged through resistors for 90 additional minutes to return the cells to the completely discharged condition (bleed portion of cycle) for the start of the next sequence of five cycles. In this manner, the cells operate below the 100 percent charged state much of the time thereby preventing overcharging and buildup of excessive gas pressure.

1. Test Equipment: The charge and discharge currents for the pack are supplied by a power supply. The rates and cycling regimen are controlled by the Sherfey cycling unit which contains the resistors used to completely discharge the cells after each fifth cycle. The cycle timing is done by using a synchronous motor timer.

2. Gulton 3.6 ah (Nickel-Cadmium with Neoprene Seal), One 10-cell Pack, 1.5-hour Orbit Period:

a. Cell Description: These are cylindrical cells with a folded neoprene seal as described in section II, paragraph I.A.4,a.

b. Test Parameters:

(1) Test Temperature: 25° C.

(2) Depth of Discharge: 40%.

c. Test Results: Cycling was started in September 1965. This pack failed on cycle 5505. Each of the cell failures was caused by the loss of electrolyte around the weld between the cell container and cell cover. Because of this leakage, which began at the start of cycling, the cells began to dry out and the charge voltage began to increase. The end-of-charge voltage gradually increased from 1.44 volts initially to 1.60 volts per cell, average, at the end of cycle life reflecting the effects of the drying out of the cells. On each successive discharge following the bleeding of every fifth cycle, the end-of-discharge voltage increased about 0.02 volt per cell.

F. Two-Step Charge Regulator: When silver-cadmium and silver-zinc cells are put on a long charge period with only a voltage limit, the cells begin to unbalance when the pack goes into overcharge. A new method of charging cells of these types was developed at Goddard Space Flight Center. Charging of the battery is by constant current to the upper voltage limit, then is automatically crossed over to constant potential. When the current decreases to a predetermined level, the constant potential charge is reset to the lower voltage limit which is equal to the open circuit voltage of the battery. The unit will not return to the upper voltage limit until the charge current goes above the predetermined value. This method prevents the cells from becoming unbalanced during long charge periods.

1. Test Equipment: The charge and discharge current is supplied by a unit described in section I, paragraph V.B. The two-step regulator, designed by the Goddard Space Flight Center, is used to control the rate of charge and the voltage limits.

2. Delco-Remy 25.0 ah (Silver-Zinc), Two 10-cell Packs, 24-hour Orbit Period:

a. Cell Description: These cells are rectangular in shape with sealed nylon cases. Each cell was individually epoxy potted by the manufacturer. The positive plates have one percent of palladium added to the active material.

b. Test Parameters:

(1) Test Temperature: 25° C.

(2) Depth of Discharge: 40%.

(3) Upper Voltage Limit: 1.97 ± 0.03 volts per cell, average.

(4) Low Current Level: 0.35 amps.

(5) Overcharge Voltage Limit: 1.87 ± 0.03 volts per cell, average.

c. Test Results:

(1) Performance on cycling:

(a) Cycling was started on Pack 9D in December 1965. This pack completed 121 cycles with two cell failures. Because of the difficulty in changing the voltage limits, as set by the two-step regulator, the Goddard Space Flight Center requested that the test be discontinued. The failed cells were returned to

the manufacturer for failure analysis. The manufacturer indicated that from his analysis the plates were in better condition than those of previous samples but that silver penetration was still a problem. Also, since no pack from the same lot was run as a control pack, the reason for improvement in this pack (9D) over previous samples cannot definitely be attributed to the Two-Step Charge Regulator.

(b) Cycling of pack 9E was started in October 1966. This pack completed 90 cycles with three cell failures. The test was discontinued at that time. The cells were returned to the manufacturer; no report on the failure analysis has been received.

3. Yardney 16.0 ah (Silver-Zinc), One 10-cell Pack, 24-hour Orbit Period (Pack 57C):

a. Cell Description: These are vented cells, rectangular in shape, with the cell jars and cell covers molded of a plastic material. They contain a limited amount of electrolyte. The cells were individually epoxy potted to hermetically seal them.

b. Test Parameters:

(1) Depth of Discharge: 31%.

(2) Upper Voltage Limit: 1.98 ± 0.03 volts per cell, average.

(3) Low Current Level: 0.10 amperes.

(4) Overcharge Voltage Limit: 1.86 ± 0.03 volts per cell, average.

(5) Test Temperature: 25° C for 100 cycles; then 0° C for 100 cycles. Repeat until pack failure occurs.

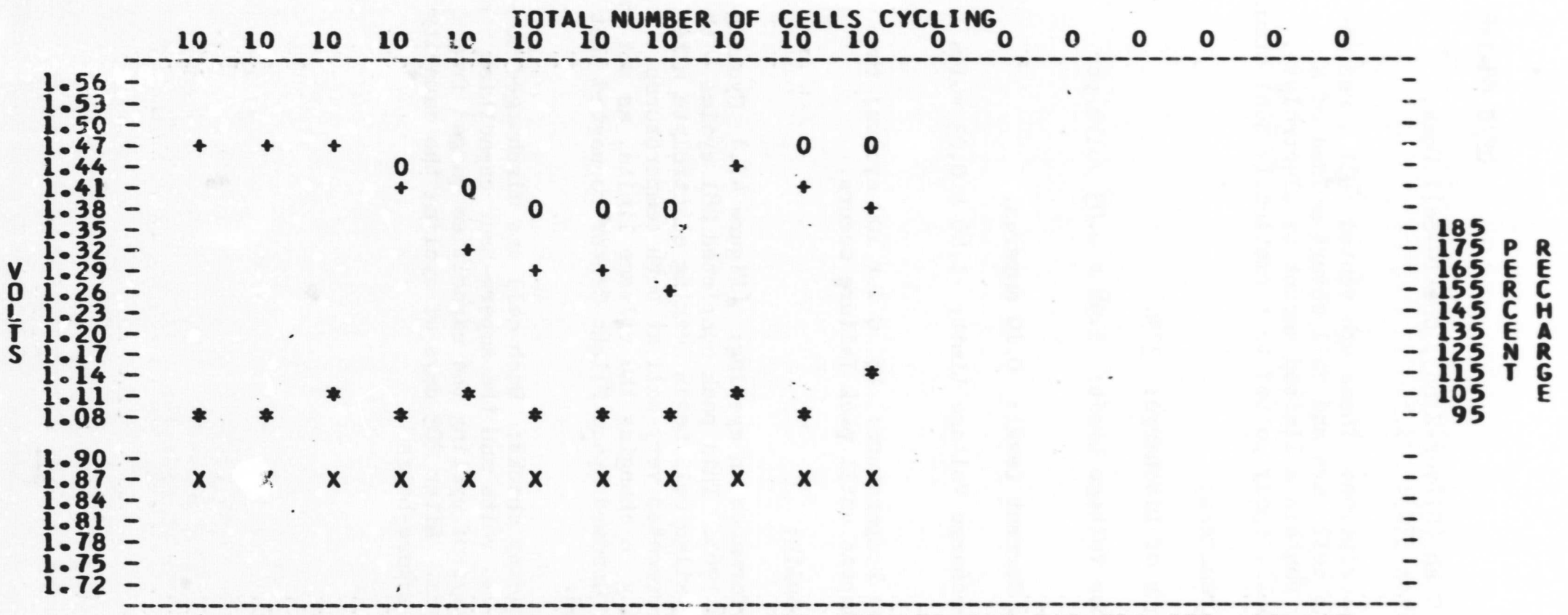
c. Test Results:

(1) Performance on cycling: (Figure 47.) Cycling was started in December 1966. This pack completed 281 cycles with one cell failure. The failed cell began leaking electrolyte after 137 cycles. The cells operated very well at both temperatures. Because of the difficulty in changing the voltage limits, as set by the two-step regulator, Goddard Space Flight Center requested that the test be discontinued.

(2) Capacity checks: Each cell was discharged to the cutoff voltage of 1.30 volts and the ampere-hour capacities determined. After 80 days of cycling the capacities ranged from 6.67 to 20.0 ampere-hours. After 203 days of cycling the capacity range was 0.67 to 18.5 ampere-hours.

KEY: O – AVERAGE CELL VOLTAGE AT MIDDLE OF DISCHARGE
+ – AVERAGE CELL VOLTAGE AT END OF DISCHARGE
* – PERCENT RECHARGE IS AMP-HOUR-IN / AMP-HOUR-OUT
X – AVERAGE CELL VOLTAGE AT END OF CHARGE

QE/C 68-138




| POS. NO. | CYCLE FAILED | | | CAPACITY CHECK CYCLES |
|---|---|---|---|---|
| 01 | 281 | PACK NUMBER | 057C | |
| | | TYPE OF CELLS | YARDNEY 16.00 AH | 4, 80, 202, |
| | | TEST TEMPERATURE | 25 DEGREES C. | |
| | | ORBIT PERIOD | 24.0 HOURS | |
| | | DEPTH OF DISCHARGE | 31 PERCENT | |
| | | SPECIFIED CHARGE RATE | 0.50 AMP. | |

STATUS PACK FAILED
ON CYCLE NUMBER 281

CYCLE 81: AMBIENT TEMPERATURE CHANGED TO ZERO DEGREES. CYCLE 203: AMBIENT TEMPERATURE CHANGED TO 25 DEGREES CENTIGRADE.

FIGURE 47

G. Internal Mechanical Pressure Devices: In certain instances the capacity output of a cell can be improved by applying pressure to the face of the plate stack. This test is designed to determine what effect, if any, a constant mechanical pressure has on the life of the cell.

1. Test Equipment: The charge and discharge current is supplied by a remotely programmed power supply.

2. Sonotone 20.0 ah (Nickel-Cadmium), Five 10-cell Packs, 1.5-hour and 3-hour Orbit Periods:

a. Cell Description: These cells are rectangular in shape. The cell container and cell cover are made of stainless steel. Both terminals are insulated from the cell cover by a teflon seal and protrude through the cover as a threaded terminal. Each cell is also fitted with a pressure relief valve. Five of the cells in each pack are standard cells; the other five contain a stainless steel eliptical spring which supplies the pressure.

b. Test Parameters:

| Pack Number | Test Temperature | Percent Depth of Discharge | Recharge Current | Charge Voltage Limit, Per Cell |
|---|---|---|---|---|
| 10A | 25° C | 25 | 7.0 Amps | 1.50 ± 0.03 |
| 22A | 25° C | 25 | 20.0 Amps | 1.50 ± 0.03 |
| 34B | 25° C | 40 | 20.0 Amps | 1.50 ± 0.03 |
| 46A* | 25° C | 40 | 20.0 Amps | 1.50 ± 0.03 |
| 72B | 25° C | 75 | 20.0 Amps | 1.50 ± 0.03 |

* This pack has an orbit period of 3 hours; all others are 1.5 hours.

c. Test Results:

(1) Performance on cycling: Cycling was started in September 1967. These packs completed from 427 to 1118 cycles, during which time a total of nine cells blew up. Cycling was stopped in November 1967 by recommendation of the manufacturer's representative. The manufacturer is running tests to determine the cause of the pressure buildup in both the control and the spring type cells. The future of this test depends upon the findings and recommendations of the manufacturer.

## III. TESTS TO BE ADDED TO THE CYCLE LIFE TEST PROGRAM

A. Nickel-Cadmium:

1. General Electric 6.0 ampere-hour cells with signal and recombination electrodes.

2. Gulton 20.0 ampere-hour auxiliary electrode cells. These cells will be tested under a continuously controlled 48-hour temperature cycle from 0° to 40° C and return. Each pack will contain a coulometer.

3. Gulton 20.0 ampere-hour cells. Some cells of these packs will contain an auxiliary electrode and/or pressure transducer. Each pack will contain a coulometer.

4. Gulton 20.0 ampere-hour cells with neoprene seals.

B. Silver-Cadmium:

1. Yardney 12.0 ampere-hour cells. The cells contain auxiliary electrodes made by Gulton for gas recombination.