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EVALUATION PROGRAM
for
SECONDARY SPACECRAFT CELLS

FIFTH ANNUAL REPORT
OF
CYCLE LIFE TEST

prepared for
GODDARD SPACE FLIGHT CENTER
CONTRACT W12,397

QUALITY EVALUATION LABORATORY
NAD CRANE, INDIANA

QUALITY EVALUATION LABORATORY
UNITED STATES NAVAL AMMUNITION DEPOT
CRANE, INDIANA

EVALUATION PROGRAM FOR SECONDARY SPACECRAFT CELLS

FIFTH ANNUAL REPORT OF CYCLE LIFE TEST

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Enclosure (1)

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REPORT BRIEF

CYCLE LIFE TEST OF SECONDARY SPACECRAFT CELLS

Ref: (a) National Aeronautics and Space Administration Purchase Order Number W12-397
(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

A. In compliance with references (a) and (b), evaluation of secondary spacecraft cells was begun according to the program outline of reference (c). This fifth annual report covers the cycle life test, the third phase of the evaluation program of secondary spacecraft cells, through 15 December 1968. 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 National Aeronautics and Space Administration, Scientific and Technical Information Division (Code US), Washington, D. C. 20546 and from Director, Defense Documentation Center, Cameron Station, Alexandria, Virginia 22314.

B. This evaluation program gathers specific information concerning cell performance characteristics and limitations which is used by spacecraft power systems planners, designers and integration teams. Weaknesses discovered in cell design are reported and aid in research and development efforts toward improving the reliability of space batteries. Failures encountered in satellite programs such as IMP, NIMBUS, OGO, and OAO have been studied and remedied through special tests performed at NAD Crane.

II. TEST OUTLINE

A. On 5 December 1963 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 3.0 to 20 ampere-hours. Since then 705 nickel-cadmium, 174

silver-cadmium and 65 silver-zinc cells from several manufacturers have been added to the program. The capacities of the nickel-cadmium cells ranged from 1.25 to 50 ampere-hours; that of the silver-cadmium cells ranged from 3.0 to 12.0 ampere-hours; and that of the silver-zinc cells ranged from 12 to 40 ampere-hours. The 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; and depth of discharge ranging from 10 to 75 percent. The charge control methods used are voltage limit, auxiliary electrode, coulometer, stabistor, a two-step regulator and the Sherfey upside-down cycling regime. 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 48 hours. A "Summary in Brief of Test Parameters" is listed on page iii.

III. TEST RESULTS

A. Life cycling data shows that cells tested at 0° C give longer cycle life, higher end-of-discharge voltages and less degradation of ampere-hour capacities than cells tested at 25° C or 40° C. Overall performance decreases with increase in the depth of discharge at all test temperatures. Cell cycle life is extended when the amount of recharge is limited to the following amounts; 105 percent at 0° C, 115 percent at 25° C and 125 percent at 40° C. Operating performance can also be improved by recharging at rates between c/2 and c/10 with the amount of recharge controlled by auxiliary electrodes or cadmium-cadmium coulometers.

B. Cell failure analyses have shown several failure modes such as little or no insulation around tabs and busses, ceramic shorts across the terminals, and leaks around the terminals which since have been corrected. A better separator material is still needed to extend cycle life of cells. Better quality control programs in the manufacturers' plants would do much to eliminate or minimize failure due to misaligned separator material, blistering of positive plates and extraneous material, both active and foreign.

C. All active and completed packs are listed on pages v through xiv. The symbols used are explained on page iv.

SUMMARY IN BRIEF OF TEST PARAMETERS

MANUFACTURER	CAPACITIES TESTED	ORBIT PERIODS	PERCENT DEPTH OF DISCHARGE	TEST TEMPERATURES	SPECIAL CHARGE CONTROL	TOTAL NO. OF CELLS
			NICKEL-CADMIUM			
GE	3.0, 5.0, 6.0, 12.0	1.5, 3.0, 24.0	15, 25, 40, 50	0°, 25°, 40°, 50°-40°, *	AE, AE13, AE14	330
Gould	3.5, 20.0	1.5, 3.0	15, 25, 40	0°, 25°, 50°-40°		180
Gulton	1.25, 3.5, 3.6, 4.0, 5.0, 5.6, 6.0, 10.0, 12.0, 20.0, 50.0	1.5, 3.0 24.0	10, 15, 25, 40, 50, 60	-20°, 0°, 25°, 50°-40°, 40°, *	AE, CLM, MULTI	590
NIFE	3.9	1.5	25	0°, 25°		10
Sonotone	3.0, 3.5, 5.0, 20.0	1.5, 3.0	15, 25, 40, 75	-20°, 0°, 25°, 50°-40°, 40°	ST, AE, IPD	255
			SILVER-CADMIUM			
ESB	8.0	8.0	25	25°	AE	5
Yardney	3.0, 5.0, 10.0, 11.0, 12.0, 24.0	1.5, 8.0, 24.0	16, 20, 27, 30, 40, 43,	-20°, 0°, 25°, 40°	AE-GE	169
			SILVER-ZINC			
Delco	25.0, 40.0	3.0, 24.0	25, 40	25°	2SR	45
Yardney	12.0, 16.0	24.0	31, 42	25°	2SR	20

EXPLANATION OF SYMBOLS

1. Temperature:

   a. * Ambient temperature which varies sinusoidally from 0° to 40° C once per 48-hour period.

2. Special Symbols:

   a. AE: Auxiliary electrode cells.

   b. AE-GE: General Electric type.

   c. AE-GU: Gulton type.

   d. AE13: General Electric type AB13.

   e. AE14: General Electric type AB14.

   f. CC: Commercial cells.

   g. CHSP: "Chemsorb" separator.

   h. CLM: Coulometer in series with cells to effect charge control.

   i. CPSP: Cellophane separator.

   j. C3SP: C3 separator.

   k. FRS: Folded seal, same type of seal as RS below.

   l. IM: Cells with improved material and methods used in construction.

   m. IPD: Cells containing an internal pressure device.

   n. NB: NIMBUS cells.

   o. NBPT: NIMBUS cells with pressure transducers.

   p. PLSP: Pellon separator.

   q. PS: Polymerized neoprene terminal to cover seal.

   r. RCPSP: Radiated cellophane separator.

   s. RS: Vulcanized neoprene terminal to cover seal.

   t. ST: Stabistors used for charge control of cells.

   u. WNSP: Woven nylon separator.

   v. 2SR: Two-step regulator used for charge control of cells.

   w. 3S: Triple seal between terminals and cover (ceramic between glass).

3. Date Completed:

   a. D: Discontinued.

   b. F: Failed.

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 COMPLETED
NICD	3.00	1.5	15%	0°	GE		63A	115	0.52	0.90	1.55	10	12-6-63	22,923	2-15-68 D
NICD	3.00	3.0	15%	0°	GE		67A	115	0.21	0.90	1.55	10	12-20-63	11,532	2-15-68 D
NICD	3.00	1.5	25%	0°	GE		64A	115	0.86	1.50	1.55	10	12-5-63	23,441	2-14-68 D
NICD	3.00	3.0	25%	0°	GE		68A	115	0.34	1.50	1.55	10	12-20-63	11,740	2-13-68 D
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 F
NICD	3.00	3.0	25%	25°	GE		19A	125	0.38	1.50	1.49	10	12-20-63	10,768	2-12-68 D
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 F
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 F
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 F
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 F
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 F
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 F
NICD	5.00	1.5	15%	0°	GE	NB	103A	110	0.83	1.50	1.49	5	4-24-65	20,463	
NICD	5.00	1.5	25%	0°	GE	NBPT	107A	110	1.38	2.50	1.49	5	6-5-65	19,856	
NICD	5.00	1.5	15%	25°	GE	NB	106A	120	0.90	1.50	1.49	5	4-24-65	20,470	
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 F
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 F
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 F
NICD	6.00	1.5	25%	0°	GE	AE-13	52C		3.00	3.00		5	6-3-68	3,040	
NICD	6.00	1.5	25%	0°	GE	AE-14	50B		3.00	3.00		5	5-20-68	3,276	
NICD	6.00	1.5	25%	25°	GE	AE-13	5B		3.00	3.00		5	5-20-68	2,529	
NICD	6.00	1.5	25%	25°	GE	AE-14	17B		3.00	3.00		5	5-20-68	3,290	
NICD	6.00	1.5	25%	40°	GE	AE-13	6C		3.00	3.00		5	6-3-68	2,998	
NICD	6.00	1.5	25%	40°	GE	AE-14	42C		3.00	3.00		5	5-20-68	3,273	
NICD	6.00	1.5	25%	*	GE	AE-13	62B		3.00	3.00		5	7-3-68	2,423	
NICD	6.00	1.5	25%	*	GE	AE-14	65B		3.00	3.00		5	7-3-68	2,539	

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 COMPLETED
NICD	6.00	1.5	15%	0°	GE	AE	53B		1.80	1.80		5	7-18-68	2,319	
NICD	6.00	1.5	15%	25°	GE	AE	28C		1.80	1.80		5	7-18-68	2,399	
NICD	6.00	1.5	15%	40°	GE	AE	47C		1.80	1.80		5	7-18-68	2,345	
NICD	6.00	1.5	25%	40°	GE	CHSP	9G		4.80	4.80		5	11-7-68	169	11-21-68 F
NICD	6.00	1.5	25%	40°	GE	PLSP	27C		4.80	4.80		5	11-7-68	559	12-16-68 D
NICD	12.00	1.5	15%	0°	GE		110A	115	2.07	3.60	1.55	5	1-4-64	26,485	
NICD	12.00	3.0	15%	0°	GE		111A	115	0.83	3.60	1.55	5	1-4-64	13,700	
NICD	12.00	1.5	25%	0°	GE		124A	115	3.45	6.00	1.55	5	1-4-64	27,060	
NICD	12.00	3.0	25%	0°	GE		125A	115	1.38	6.00	1.55	5	1-4-64	13,772	
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 F
NICD	12.00	3.0	25%	25°	GE		83A	125	1.50	6.00	1.49	5	1-4-64	13,601	
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 F
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 F
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 F
NICD	12.00	3.0	15%	40°	GE		86A	160	1.15	3.60	1.45	5	1-4-64	10,661	1-2-68 F
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 F
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 F
NICD	12.00	24.0	50%	25°	GE		93A	115	0.52	6.00	1.45	5	3-28-64	349	4-28-65 D
NICD	12.00	1.5	25%	0°	GE	AE	60A		6.00	6.00		5	10-6-65	5,650	10-20-66 F
NICD	12.00	1.5	25%	25°	GE	AE	12A		6.00	6.00		5	7-20-65	1,698	12-1-65 D
NICD	12.00	1.5	40%	25°	GE	AE	24A		9.60	9.60		5	10-2-65	665	11-19-65 D
NICD	12.00	1.5	25%	0°	GE	AE	48A		9.60	9.60		5	10-12-65	5,110	2-10-67 D
NICD	12.00	1.5	25%	0°	GE	AE	58A		6.00	6.00		5	1-20-67	136	2-10-67 D
NICD	12.00	1.5	40%	0°	GE	AE	72A		6.00	6.00		5	1-20-67	304	2-2-67 D
NICD	12.00	1.5	25%	25°	GE	AE	12B		6.00	6.00		5	1-6-67	404	2-10-67 D
NICD	12.00	1.5	40%	25°	GE	AE	24B		6.00	9.60		5	1-5-67	38	2-10-67 D

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 COMPLETED	
NICD	12.00	1.5	25%	40°	GE	AE	36A		6.00	6.00		5	1-27-67	75	2-3-67	D
NICD	12.00	1.5	40%	40°	GE	AE	34A		6.00	9.60		5	1-27-67	65	2-3-67	D
NICD	3.50	1.5	15%	0°	GOULD		51A	115	0.60	1.05	1.55	10	12-5-63	22,364	2-15-68	D
NICD	3.50	3.0	15%	0°	GOULD		55A	115	0.24	1.05	1.55	10	12-20-63	11,546	2-15-68	D
NICD	3.50	1.5	25%	0°	GOULD		52A	115	1.00	1.75	1.55	10	12-5-63	13,730	6-11-66	F
NICD	3.50	3.0	25%	0°	GOULD		56A	115	0.40	1.75	1.55	10	12-20-63	11,897	2-15-68	D
NICD	3.50	1.5	25%	25°	GOULD		3A	125	1.09	1.75	1.49	10	12-6-63	4,751	10-31-64	F
NICD	3.50	3.0	25%	25°	GOULD		7A	125	0.44	1.75	1.49	10	12-20-63	4,173	7-26-65	F
NICD	3.50	1.5	40%	25°	GOULD		4A	125	1.75	2.80	1.49	10	12-5-63	3,164	7-9-64	F
NICD	3.50	3.0	40%	25°	GOULD		8A	125	0.70	2.80	1.49	10	12-20-63	2,494	11-29-64	F
NICD	3.50	1.5	15%	40°	GOULD		27A	160	0.84	1.05	1.45	10	12-12-63	4,485	11-6-64	F
NICD	3.50	3.0	15%	40°	GOULD		31A	160	0.34	1.05	1.45	10	12-20-63	2,517	1-3-65	F
NICD	3.50	1.5	25%	40°	GOULD		28A	160	1.40	1.75	1.45	10	12-12-63	1,811	5-29-64	F
NICD	3.50	3.0	25%	40°	GOULD		32A	160	0.56	1.75	1.45	10	12-20-63	975	6-10-64	F
NICD	20.00	1.5	15%	0°	GOULD		84A	115	3.45	6.00	1.55	5	1-16-64	22,448	2-13-68	D
NICD	20.00	3.0	15%	0°	GOULD		80A	115	1.38	6.00	1.55	5	1-21-64	11,378	2-13-68	D
NICD	20.00	1.5	25%	0°	GOULD		98A	115	5.75	10.00	1.55	5	1-21-64	10,641	1-14-66	F
NICD	20.00	3.0	25%	0°	GOULD		94A	115	2.30	10.00	1.55	5	1-24-64	11,162	2-13-68	D
NICD	20.00	1.5	25%	25°	GOULD		104A	125	6.25	10.00	1.49	5	1-16-64	2,980	8-20-64	F
NICD	20.00	3.0	25%	25°	GOULD		105A	125	2.50	10.00	1.49	5	1-21-64	5,690	3-17-66	F
NICD	20.00	1.5	40%	25°	GOULD		118A	125	10.00	16.00	1.49	5	2-1-64	2,937	9-7-64	F
NICD	20.00	3.0	40%	25°	GOULD		119A	125	4.00	16.00	1.49	5	2-1-64	1,793	9-27-64	F
NICD	20.00	1.5	15%	40°	GOULD		112A	160	4.80	6.00	1.45	5	1-16-64	5,213	2-15-65	F
NICD	20.00	3.0	15%	40°	GOULD		108A	160	1.92	6.00	1.45	5	1-24-64	4,273	8-31-65	F
NICD	20.00	1.5	25%	40°	GOULD		126A	160	8.00	10.00	1.45	5	1-16-64	1,574	5-23-64	F
NICD	20.00	3.0	25%	40°	GOULD		122A	160	3.20	10.00	1.45	5	1-24-64	983	7-2-64	F

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 COMPLETED
NICD	1.25	1.5	25%	-20°	GULTON		74B		1.00	0.63		5	3-3-66	15,385	
NICD	1.25	1.5	60%	-20°	GULTON		88D		1.00	0.63		5	3-3-66	14,774	
NICD	1.25	1.5	25%	0°	GULTON		108B		1.25	0.63		5	3-4-66	15,688	
NICD	1.25	1.5	60%	0°	GULTON		98B		1.25	1.50		5	3-4-66	12,247	5-28-68 F
NICD	3.50	1.5	25%	-20°	GULTON	PS	89C	110	0.96	1.75	1.56	5	12-24-66	11,088	
NICD	3.50	1.5	40%	-20°	GULTON	PS	75D	110	1.54	2.80	1.56	5	12-24-66	9,866	
NICD	3.50	1.5	25%	0°	GULTON	PS	122C	115	1.01	1.75	1.55	5	12-24-66	11,168	
NICD	3.50	1.5	40%	0°	GULTON	PS	99C	115	1.61	2.80	1.55	5	12-24-66	11,088	
NICD	3.50	1.5	25%	25°	GULTON	PS	87C	125	1.09	1.75	1.49	5	12-23-66	11,185	
NICD	3.50	1.5	25%	40°	GULTON	PS	112C	160	1.40	1.75	1.45	5	1-2-67	10,865	
NICD	3.50	1.5	40%	25°	GULTON	PS	73C	125	1.75	2.80	1.49	5	12-23-66	9,978	10-28-68 F
NICD	3.60	1.5	40%	25°	GULTON	CLM	39B		3.60	2.88	1.49	10	11-11-65	5,399	12-6-66 F
NICD	4.00	1.5	15%	0°	GULTON	CC	115B	115	0.69	1.20	1.55	5	7-25-64	24,307	
NICD	4.00	1.5	25%	0°	GULTON	CC	126B	115	1.15	2.00	1.55	5	7-25-64	24,756	
NICD	4.00	1.5	25%	25°	GULTON	CC	4B	125	1.25	2.00	1.49	5	8-4-64	24,476	
NICD	4.00	1.5	40%	25°	GULTON	CC	14B	125	2.00	3.20	1.49	5	8-4-64	8,474	3-19-66 F
NICD	4.00	1.5	15%	40°	GULTON	CC	28B	160	0.96	1.20	1.45	5	8-4-64	20,227	7-6-68 F
NICD	4.00	1.5	25%	40°	GULTON	CC	40B	160	1.60	2.00	1.45	5	8-4-64	10,360	6-22-66 F
NICD	4.00	1.5	25%	-20°	GULTON	CLM	40C		2.00	2.00	1.56	5	3-4-67	2	3-4-67 F
NICD	4.00	1.5	25%	0°	GULTON	CLM	52B		2.00	2.00	1.48	5	3-3-67	5,685	3-5-68 F
NICD	4.00	1.5	15%	25°	GULTON	CLM	26C		1.20	1.20	1.44	5	2-18-67	10,317	
NICD	4.00	1.5	25%	25°	GULTON	CLM	14C		2.00	2.00	1.44	5	3-3-67	2,428	8-8-67 F
NICD	4.00	1.5	40%	25°	GULTON	CLM	37C		4.80	4.80	1.44	5	3-4-67	790	5-5-67 F
NICD	4.00	1.5	60%	25°	GULTON	CLM	38D		3.20	3.20	1.44	5	2-18-67	1,927	6-27-67 F
NICD	4.00	1.5	25%	40°	GULTON	CLM	39C		2.00	2.00	1.38	5	3-3-67	1,508	6-20-67 F
NICD	5.00	1.5	15%	0°	GULTON	NB	117A	110	0.83	1.50	1.49	5	5-8-65	20,057	

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 COMPLETED	
NICD	5.00	1.5	25%	0°	GULTON	NBPT	121A	110	1.38	2.50	1.49	5	6-5-65	19,642		
NICD	5.00	1.5	15%	25°	GULTON	NB	120A	120	0.90	1.50	1.49	5	5-2-65	19,096		
NICD	5.00	1.5	25%	25°	GULTON	NBPT	118B	120	1.50	2.50	1.49	5	6-10-65	8,108	11-22-66	F
NICD	5.00	1.5	15%	40°	GULTON	NB	127A	130	0.98	1.50	1.49	5	4-29-65	10,638	5-24-67	F
NICD	5.00	1.5	25%	40°	GULTON	NBPT	128A	130	1.63	2.50	1.49	5	6-12-65	6,345	8-18-66	F
NICD	5.60	1.5	25%	-20°	GULTON	FRS	44B	115	1.61	2.80	1.60	5	1-2-66	16,579		
NICD	5.60	1.5	25%	-20°	GULTON	RS	32B	115	1.61	2.80	1.60	5	1-2-66	16,473		
NICD	5.60	1.5	25%	0°	GULTON	FRS	100B	115	1.61	2.80	1.55	5	12-17-65	16,745		
NICD	5.60	1.5	25%	0°	GULTON	RS	90C	115	1.61	2.80	1.55	5	12-17-65	16,831		
NICD	5.60	1.5	25%	25°	GULTON	FRS	76B	125	1.75	2.80	1.49	5	12-10-65	11,158	1-2-68	F
NICD	5.60	1.5	25%	25°	GULTON	RS	96C	125	1.75	2.80	1.49	5	12-10-65	9,791	9-19-67	F
NICD	5.60	1.5	25%	40°	GULTON	FRS	42B	160	2.24	2.80	1.45	5	12-3-65	3,798	9-10-66	F
NICD	5.60	1.5	25%	40°	GULTON	RS	30B	160	2.24	2.80	1.45	5	12-3-65	1,275	3-8-66	F
NICD	6.00	1.5	15%	0°	GULTON		61A	115	1.04	1.80	1.55	10	12-31-63	10,146	12-17-65	F
NICD	6.00	3.0	15%	0°	GULTON		65A	115	0.41	1.80	1.55	10	12-31-63	11,208	2-15-68	D
NICD	6.00	1.5	25%	0°	GULTON		62A	115	1.72	3.00	1.55	10	12-30-63	22,779	2-15-68	D
NICD	6.00	3.0	25%	0°	GULTON		66A	115	0.69	3.00	1.55	10	12-31-63	4,414	8-31-65	F
NICD	6.00	1.5	25%	25°	GULTON		13A	125	1.88	3.00	1.49	10	12-31-63	4,021	11-11-64	F
NICD	6.00	3.0	25%	25°	GULTON		17A	125	0.75	3.00	1.49	10	12-20-63	2,885	1-31-65	F
NICD	6.00	1.5	25%	25°	GULTON		14A	125	3.00	4.80	1.49	10	12-30-63	2,086	6-19-64	F
NICD	6.00	3.0	40%	25°	GULTON		18A	125	1.20	4.80	1.49	10	12-31-63	1,500	8-18-64	F
NICD	6.00	1.5	15%	40°	GULTON		37A	160	1.44	1.80	1.45	10	12-31-63	6,064	4-14-65	F
NICD	6.00	3.0	15%	40°	GULTON		41A	160	0.58	1.80	1.45	10	12-31-63	1,689	9-14-64	F
NICD	6.00	1.5	25%	40°	GULTON		38A	160	2.40	3.00	1.45	10	12-30-63	1,377	5-22-64	F
NICD	6.00	3.0	25%	40°	GULTON		42A	160	0.96	3.00	1.45	10	12-31-63	4,133	8-23-65	F
NICD	6.00	24.0	50%	25°	GULTON		79A	115	0.20	3.00	1.49	5	3-28-64	545	10-13-65	F

	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 COMPLETED	
	NICD	6.00	1.5	25%	0°	GULTON	IM	13B	115	1.73	3.00	1.55	5	2-22-65	21,529		
	NICD	6.00	1.5	40%	25°	GULTON	IM	18B	125	3.00	4.80	1.49	5	2-22-65	7,577	7-21-66	F
	NICD	6.00	1.5	25%	40°	GULTON	IM	38B	160	2.40	3.00	1.45	5	2-22-65	5,766	3-31-66	F
	NICD	6.00	1.5	10%	0°	GULTON		61B	110	0.66	1.20	1.55	10	6-7-67	8,570		
	NICD	6.00	1.5	25%	0°	GULTON	AE	59A		3.00	3.00		5	4-15-65	14,863	2-28-68	F
	NICD	6.00	1.5	40%	0°	GULTON	AE	71A		4.80	4.80		5	4-15-65	5,753	5-18-66	F
	NICD	6.00	1.5	25%	25°	GULTON	AE	23A		3.00	3.00		5	2-5-65	15,713	1-24-68	F
	NICD	6.00	1.5	40%	25°	GULTON	AE	11A		4.80	4.80		5	2-5-65	7,743	7-9-66	F
	NICD	6.00	1.5	15%	40°	GULTON	AE	35A		1.80	1.80		5	6-28-65	12,511	11-30-67	F
	NICD	6.00	1.5	25%	40°	GULTON	AE	47A		3.00	3.00		5	5-16-65	5,502	5-11-66	F
	NICD	6.00	1.5	15%	*	GULTON	AE	60B		1.80	1.80		5	4-25-67	9,514		
	NICD	6.00	1.5	25%	*	GULTON	AE	24C		3.00	3.00		5	4-25-67	9,495		
x	NICD	6.00	1.5	40%	*	GULTON	AE	48B		4.80	4.80		5	4-25-67	6,156	6-27-68	F
	NICD	6.00	3.0	25%	-20°	GULTON	CLM	41B		3.00	3.00		5	11-18-66	5,695		
	NICD	6.00	3.0	25%	0°	GULTON	CLM	66B		3.00	3.00		5	11-18-66	5,898		
	NICD	6.00	3.0	25%	25°	GULTON	CLM	18C		3.00	3.00		5	11-18-66	5,465		
	NICD	6.00	3.0	25%	40°	GULTON	CLM	29B		3.00	3.00		5	11-18-66	5,833		
	NICD	10.00	1.5	40%	25°	GULTON	AE	8B		5.00	5.00		5	11-27-67	2,414	5-6-68	F
	NICD	10.00	1.5	40%	40°	GULTON	AE	6B		5.00	5.00		5	11-27-67	602	3-14-68	F
	NICD	12.00	1.5	15%	0°	GULTON		16B	115	2.07	3.60	1.55	5	2-20-65	21,529		
	NICD	12.00	1.5	25%	0°	GULTON		101B	115	3.45	6.00	1.55	5	12-19-64	22,308		
	NICD	12.00	1.5	25%	25°	GULTON		27B	125	3.75	6.00	1.49	5	1-28-65	14,250	9-5-67	F
	NICD	12.00	1.5	40%	25°	GULTON		96B	125	6.00	9.60	1.49	5	12-2-64	5,152	11-9-65	F
	NICD	12.00	1.5	15%	40°	GULTON		78A	160	2.88	3.60	1.45	5	12-22-64	11,081	1-4-66	F
	NICD	12.00	1.5	25%	40°	GULTON		90B	160	8.00	10.00	1.45	5	12-5-64	5,124	11-10-65	F
	NICD	12.00	1.5	25%	0°	GULTON	AE	70A		6.00	6.00		5	2-10-67	10,440		

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 COMPLETED	
NICD	12.00	1.5	40%	0°	GULTON	AE	71B		6.00	9.60		5	1-6-67	10,705		
NICD	12.00	1.5	40%	25°	GULTON	AE	11B		6.00	9.60		5	10-17-66	11,858		
NICD	12.00	1.5	25%	40°	GULTON	AE	47B		6.00	6.00		5	1-5-67	6,537	6-19-68	F
NICD	20.00	1.5	15%	0°	GULTON		101A	115	3.45	6.00	1.55	5	1-16-64	3,629	9-20-64	F
NICD	20.00	3.0	15%	0°	GULTON		102A	115	1.38	6.00	1.55	5	1-21-64	11,212	2-13-68	D
NICD	20.00	1.5	25%	0°	GULTON		115A	115	5.75	10.00	1.55	5	1-16-64	2,291	6-24-64	F
NICD	20.00	3.0	25%	0°	GULTON		116A	115	2.30	10.00	1.55	5	2-11-64	10,971	2-13-68	D
NICD	20.00	1.5	25%	25°	GULTON		73A	125	6.25	10.00	1.49	5	1-16-64	7,763	6-30-65	F
NICD	20.00	3.0	25%	25°	GULTON		74A	125	2.50	10.00	1.49	5	1-21-64	1,754	9-27-64	F
NICD	20.00	1.5	40%	25°	GULTON		87A	125	10.00	16.00	1.49	5	2-1-64	627	4-7-64	F
NICD	20.00	3.0	40%	25°	GULTON		88A	125	4.00	16.00	1.49	5	2-1-64	358	3-21-64	F
NICD	20.00	1.5	15%	40°	GULTON		76A	160	4.80	6.00	1.45	5	1-18-64	9,348	10-15-65	F
NICD	20.00	3.0	15%	40°	GULTON		77A	160	1.92	6.00	1.45	5	1-21-64	6,032	4-20-66	F
NICD	20.00	1.5	25%	40°	GULTON		90A	160	8.00	10.00	1.45	5	1-18-64	4,045	11-12-64	F
NICD	20.00	3.0	25%	40°	GULTON		91A	160	3.20	10.00	1.45	5	1-24-64	4,480	10-14-65	F
NICD	20.00	1.5	15%	0°	GULTON	AE	58B		5.00	6.00		5	4-8-67	4,026	1-25-68	D
NICD	20.00	1.5	15%	25°	GULTON	AE	12C		5.00	6.00		5	3-9-67	4,934	1-25-68	F
NICD	20.00	1.5	15%	40°	GULTON	AE	36B		5.00	6.00		5	3-11-67	2,740	9-5-67	D
NICD	20.00	1.5	15%	*	GULTON	MULTI	12D		10.00	6.00		5	2-8-68	4,950		
NICD	20.00	1.5	25%	*	GULTON	MULTI	36C		10.00	10.00		5	2-8-68	966	8-14-68	D
NICD	20.00	1.5	40%	*	GULTON	MULTI	58C		10.00	16.00		5	2-8-68	131	3-2-68	F
NICD	20.00	1.5	15%	0°	GULTON	AE	54B		8.00	6.00		5	3-23-68	4,254		
NICD	20.00	1.5	15%	25°	GULTON	AE	19B		8.00	6.00		5	3-23-68	4,246		
NICD	20.00	1.5	15%	40°	GULTON	AE	38E		8.00	6.00		5	3-23-68	4,335		
NICD	50.00	1.5	25%	0°	GULTON		95A	115	14.38	25.00	1.55	5	6-8-64	3,227	2-9-65	F
NICD	50.00	1.5	15%	40°	GULTON		123A	160	12.00	15.00	1.45	5	6-8-64	1,878	11-11-64	F

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 COMPLETED
NICD	3.90	1.5	25%	0°	NIFE		97C	107	1.07	2.00	1.50	5	9-29-67	6,936	
NICD	3.90	1.5	25%	25°	NIFE		85C	107	1.07	2.00	1.50	5	9-29-67	6,581	
NICD	3.00	1.5	15%	0°	SONOTONE	3S	43B	115	0.52	0.90	1.55	5	6-24-65	19,058	
NICD	3.00	1.5	25%	0°	SONOTONE	3S	31B	115	0.86	1.50	1.55	5	6-24-65	18,735	
NICD	3.00	1.5	25%	25°	SONOTONE	3S	3B	125	0.94	1.50	1.49	5	6-25-65	11,726	8-23-67 F
NICD	3.00	1.5	40%	25°	SONOTONE	3S	2B	125	1.50	2.40	1.49	5	7-10-65	5,399	7-26-66 F
NICD	3.00	1.5	15%	40°	SONOTONE	3S	26B	160	0.72	0.90	1.45	5	7-10-65	6,289	10-4-66 F
NICD	3.00	1.5	25%	40°	SONOTONE	3S	37B	160	1.20	1.50	1.45	5	7-10-65	5,625	8-4-66 F
NICD	3.50	1.5	10%	0°	SONOTONE		15B	110	0.39	0.70	1.55	10	6-7-67	8,538	
NICD	5.00	1.5	15%	0°	SONOTONE		49A	115	0.86	1.50	1.55	10	12-31-63	23,112	2-15-68 D
NICD	5.00	3.0	15%	0°	SONOTONE		53A	115	0.35	1.50	1.55	10	12-31-63	11,427	2-13-68 D
NICD	5.00	1.5	25%	0°	SONOTONE		50A	115	1.44	2.50	1.55	10	12-17-63	22,525	2-15-68 D
NICD	5.00	3.0	25%	0°	SONOTONE		54A	115	0.58	2.50	1.55	10	12-31-63	11,331	2-7-68 D
NICD	5.00	1.5	25%	25°	SONOTONE		1A	125	1.56	2.50	1.49	10	12-17-63	11,745	2-27-66 F
NICD	5.00	3.0	25%	25°	SONOTONE		5A	125	0.62	2.50	1.49	10	12-31-63	11,092	2-12-68 D
NICD	5.00	1.5	40%	25°	SONOTONE		2A	125	2.50	4.00	1.49	10	12-17-63	6,671	4-24-65 F
NICD	5.00	3.0	40%	25°	SONOTONE		6A	125	1.00	4.00	1.49	10	1-2-64	5,211	12-13-65 F
NICD	5.00	1.5	15%	40°	SONOTONE		25A	160	1.20	1.50	1.45	10	12-17-63	9,328	10-31-65 F
NICD	5.00	3.0	15%	40°	SONOTONE		29A	160	0.48	1.50	1.45	10	12-31-63	5,975	4-17-66 F
NICD	5.00	1.5	25%	40°	SONOTONE		26A	160	2.00	2.50	1.45	10	12-17-63	3,625	10-15-64 F
NICD	5.00	3.0	25%	40°	SONOTONE		30A	160	0.80	2.50	1.45	10	12-31-63	4,141	8-7-65 F
NICD	5.00	1.5	25%	-20°	SONOTONE	ST	75C		5.00	2.50		5	10-24-65	2,145	4-5-66 F
NICD	5.00	1.5	40%	-20°	SONOTONE	ST	89B		5.00	4.00		5	10-24-65	1,530	2-26-66 F
NICD	5.00	1.5	25%	0°	SONOTONE	ST	92A		5.00	2.50		5	9-5-65	8,774	5-10-67 F
NICD	5.00	1.5	40%	0°	SONOTONE	ST	122B		5.00	4.00		5	9-5-65	5,190	9-24-66 F
NICD	5.00	1.5	25%	25°	SONOTONE	ST	73B		5.00	2.50		5	8-12-65	3,742	4-15-66 F

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 COMPLETED
NICD	5.00	1.5	40%	25°	SONOTONE	ST	87B		5.00	4.00		5	8-12-65	2,392	1-27-66 F
NICD	5.00	1.5	25%	40°	SONOTONE	ST	99B		5.00	2.50		5	8-23-65	4,388	7-9-66 F
NICD	5.00	1.5	15%	40°	SONOTONE	ST	112B		5.00	1.50		5	8-23-65	3,294	4-1-66 F
NICD	5.00	1.5	25%	25°	SONOTONE	AE	14D		2.50	1.47	1.50	5	11-7-67	1,179	2-7-68 F
NICD	20.00	1.5	25%	25°	SONOTONE	IPD	22A		20.00	10.00	1.50	10	9-20-67	2,196	
NICD	20.00	1.5	25%	25°	SONOTONE	IPD	10A		7.00	10.00	1.49	10	9-20-67	2,715	
NICD	20.00	1.5	40%	25°	SONOTONE	IPD	34B		20.00	16.00	1.50	10	9-20-67	2,540	
NICD	20.00	3.0	40%	25°	SONOTONE	IPD	46A		20.00	16.00	1.50	10	9-20-67	1,225	
NICD	20.00	1.5	75%	25°	SONOTONE	IPD	72B		20.00	30.00	1.50	10	9-20-67	610	
AGCD	8.00	8.0	25%	25°	ESB	AE	1B		0.50	2.00	1.51	5	9-9-66	2,371	
AGCD	3.00	1.5	16%	25°	YARDNEY		2C		1.30	1.00	1.52	9	9-16-66	7,039	12-12-67 F
AGCD	5.00	24.0	20%	0°	YARDNEY	C3SP	57B		0.30	1.00	1.50	5	9-17-65	267	6-17-66 F
AGCD	5.00	24.0	20%	25°	YARDNEY	C3SP	21A		0.30	1.00	1.50	5	9-17-65	98	12-25-65 F
AGCD	5.00	24.0	20%	40°	YARDNEY	C3SP	45A		0.30	1.00	1.50	5	9-27-65	61	11-16-65 F
AGCD	5.00	24.0	20%	25°	YARDNEY	RCPSP	9C		1.00	10.00	1.50	10	10-27-65	34	12-1-65 D
AGCD	5.00	24.0	20%	25°	YARDNEY	CPSP	33B		0.30	1.00	1.49	5	10-17-65	720	11-4-67 F
AGCD	5.00	24.0	20%	25°	YARDNEY	PLSP	69A		0.30	1.00	1.50	5	10-27-65	595	7-17-67 F
AGCD	5.00	8.0	20%	0°	YARDNEY		114B		0.30	1.00	1.50	5	1-22-67	1,496	6-25-68 F
AGCD	5.00	24.0	20%	0°	YARDNEY		113B		0.30	1.00	1.50	5	1-22-67	700	
AGCD	5.00	8.0	20%	25°	YARDNEY		118C		0.30	1.00	1.50	5	1-17-67	1,505	7-9-68 F
AGCD	5.00	24.0	20%	25°	YARDNEY		77B		0.30	1.00	1.50	5	1-12-67	661	11-12-68 F
AGCD	5.00	24.0	20%	25°	YARDNEY		105B		0.30	1.00	1.50	5	1-12-67	77	4-19-67 F
AGCD	5.00	24.0	20%	40°	YARDNEY		128B		0.30	1.00	1.50	5	1-19-67	269	11-4-67 F
AGCD	10.00	8.0	30%	25°	YARDNEY		45D		0.50	3.00	1.51	5	5-3-67	1,759	11-19-68 F
AGCD	11.00	24.0	40%	0°	YARDNEY		45B		0.30	4.40	1.51	10	11-5-66	121	3-13-67 F
AGCD	11.00	24.0	40%	25°	YARDNEY		21B		0.30	4.40	1.51	10	11-5-66	69	1-13-67 F

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 COMPLETED	
AGCD	11.00	8.0	27%	25°	YARDNEY	PLSP	21C		0.50	3.00	1.51	5	3-28-67	37	4-9-67	F
AGCD	11.00	8.0	27%	25°	YARDNEY	WNSP	45C		0.50	3.00	1.51	5	3-28-67	70	4-22-67	F
AGCD	11.00	24.0	18%	0°	YARDNEY	AE-GU	57D		0.25	2.00		5	2-14-68	295		
AGCD	11.00	24.0	18%	25°	YARDNEY	AE-GU	69B		0.25	2.00		5	2-14-68	304		
AGCD	11.00	24.0	18%	40°	YARDNEY	AE-GU	33C		0.25	2.00		5	2-14-68	303		
AGCD	12.00	24.0	50%	0°	YARDNEY		57A		0.60	6.00	1.50	10	2-14-64	168	9-3-64	F
AGCD	12.00	24.0	50%	40°	YARDNEY		33A		0.60	6.00	1.50	10	2-14-64	210	9-20-64	F
AGCD	12.00	1.5	25%	-20°	YARDNEY		85B		3.90	6.00	1.60	5	1-19-66	2,375	3-25-67	F
AGCD	12.00	1.5	25%	0°	YARDNEY		97B		3.90	6.00	1.58	5	1-19-66	4,481	3-15-67	F
AGCD	12.00	1.5	25%	25°	YARDNEY		82B		3.90	6.00	1.55	5	1-17-66	4,559	11-27-66	F
AGCD	12.00	24.0	43%	0°	YARDNEY	AE-GE	21D		0.50	5.20	1.51	5	6-16-67	60	8-13-67	F
AGCD	12.00	24.0	43%	40°	YARDNEY	AE-GE	9F		0.50	5.20	1.51	5	6-16-67	310	5-28-68	F
AGZN	25.00	24.0	40%	25°	DELCO-REMY		89A		15.00	10.00	1.97	5	9-18-64	80	12-8-64	D
AGZN	25.00	24.0	40%	25°	DELCO-REMY		75A		15.00	10.00	1.97	5	8-18-64	32	9-18-64	F
AGZN	25.00	3.0	40%	25°	DELCO-REMY		88B		15.00	20.00	1.97	5	3-1-65	120	3-16-65	D
AGZN	25.00	3.0	40%	25°	DELCO-REMY		88C		15.00	20.00	1.97	5	3-26-65	325	5-6-65	D
AGZN	25.00	24.0	40%	25°	DELCO-REMY	2SR	9D		1.00	10.00	1.97	10	12-13-65	121	4-18-66	D
AGZN	25.00	24.0	40%	25°	DELCO-REMY	2SR	9E		1.00	10.00	1.97	10	10-5-66	90	1-4-67	D
AGZN	40.00	24.0	25%	25°	DELCO-REMY		75B		25.00	10.00	1.97	5	10-28-64	139	3-15-65	D
AGZN	12.00	24.0	42%	25°	YARDNEY		9A		0.50	5.00	1.97	10	5-7-65	58	7-7-65	D
AGZN	16.00	24.0	31%	25°	YARDNEY	2SR	57C		0.50	5.00	2.00	10	12-2-66	281	8-30-67	D

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 fifth annual report summarizes the cycle life test work from 5 December 1963 through 15 December 1968 with the exception of the graphs on data that was gathered before December 1967. The purpose of the cycle program is to determine the cycling performance capabilities of packs of cells under different load and temperature conditions. The cycle life test is the third phase of the evaluation program of secondary spacecraft cells. The acceptance tests and general performance tests, the first two phases of this program, were reported earlier.

C. Section I of this report refers only to the original 660 nickel-cadmium cells containing nonwoven nylon separators on which this activity began the life cycle test on 5 December 1963. The cells were purchased by the National Aeronautics and Space Administration from four manufacturers, and consisted of seven sample classifications ranging from 3.0 to 20 ampere-hours. The cycling load conditions include cycle lengths (orbit periods) of 1.5 and 3.0 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 their respective cells have failed.

D. Section II covers the cycle life testing done on 705 nickel-cadmium cells, which contained nonwoven nylon separators unless otherwise indicated; 174 silver-cadmium cells, which contained cellophane separators unless otherwise indicated; and 65 silver-zinc cells, which contained cellophane separators unless otherwise indicated; from several manufacturers that have been added to the program. The program has been extended to include cycle lengths (orbit periods) of 8.0 and 24 hours, and depths of discharge ranging from 10 to 75 percent. Environmental conditions have been extended to include ambient temperatures of -20° C and one temperature cycle that varies sinusoidally from 0° to 40° C in 48 hours with normal atmospheric conditions.

SECTION I

ORIGINAL CYCLE LIFE TEST PROGRAM

I. CELL DESCRIPTION

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

1. General Electric Company (GE):

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.

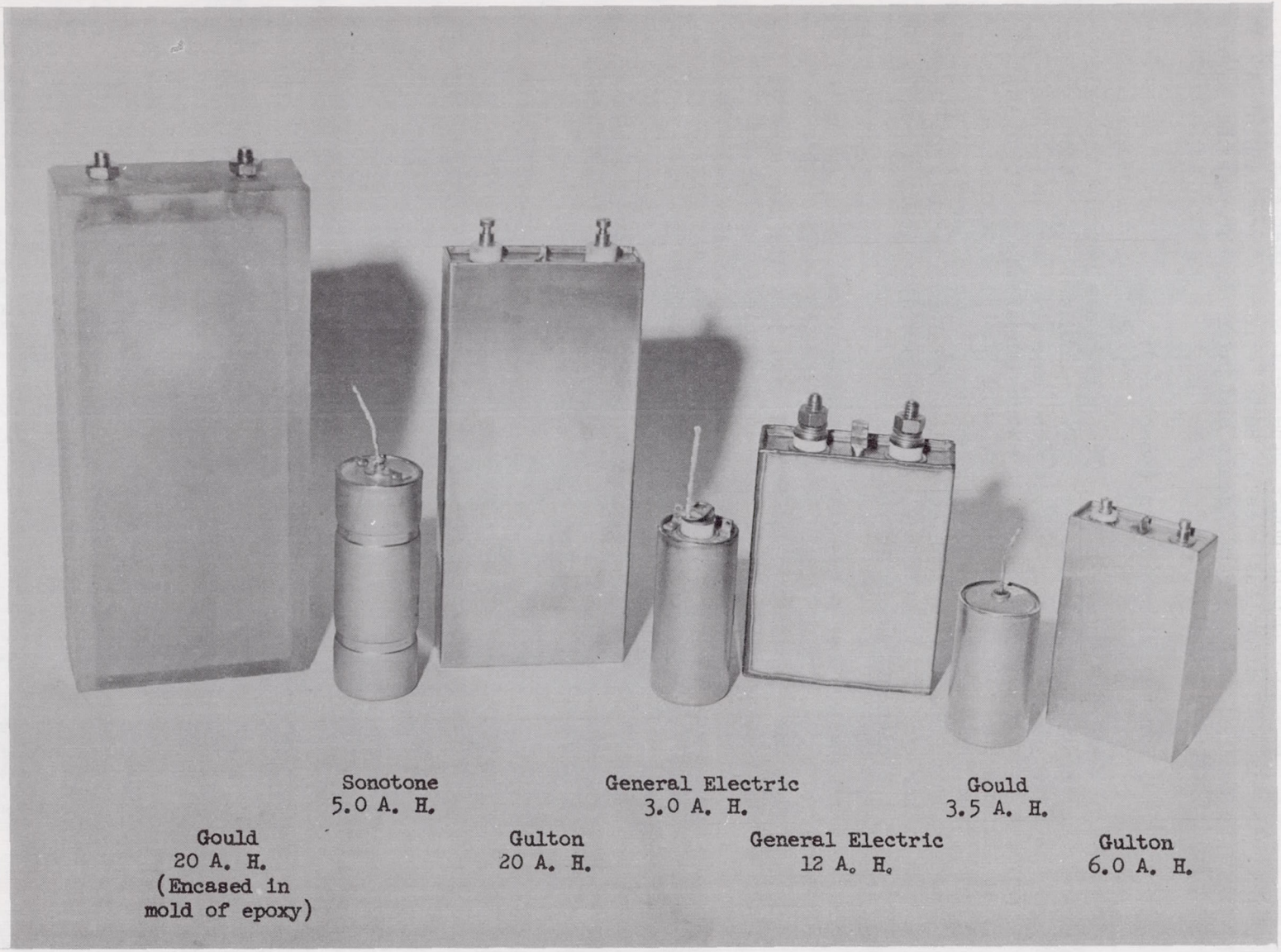
b. 20.0 Ampere-hour: The cell container and the cell cover are made of stainless steel. Both terminals are insulated from the cell cover by ceramic seals and protrude through the cover as solder type terminals.

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

II. 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 or is discontinued.

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 maximum percentages of recharge, which may be less due to voltage limits (see paragraph II.B.3.d.).

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

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

(3) 40° ± 2° C, with 160 percent maximum 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 each of the 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. On-charge voltage limits were specified for each 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 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 four remaining packs were left cycling at 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 III.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:

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

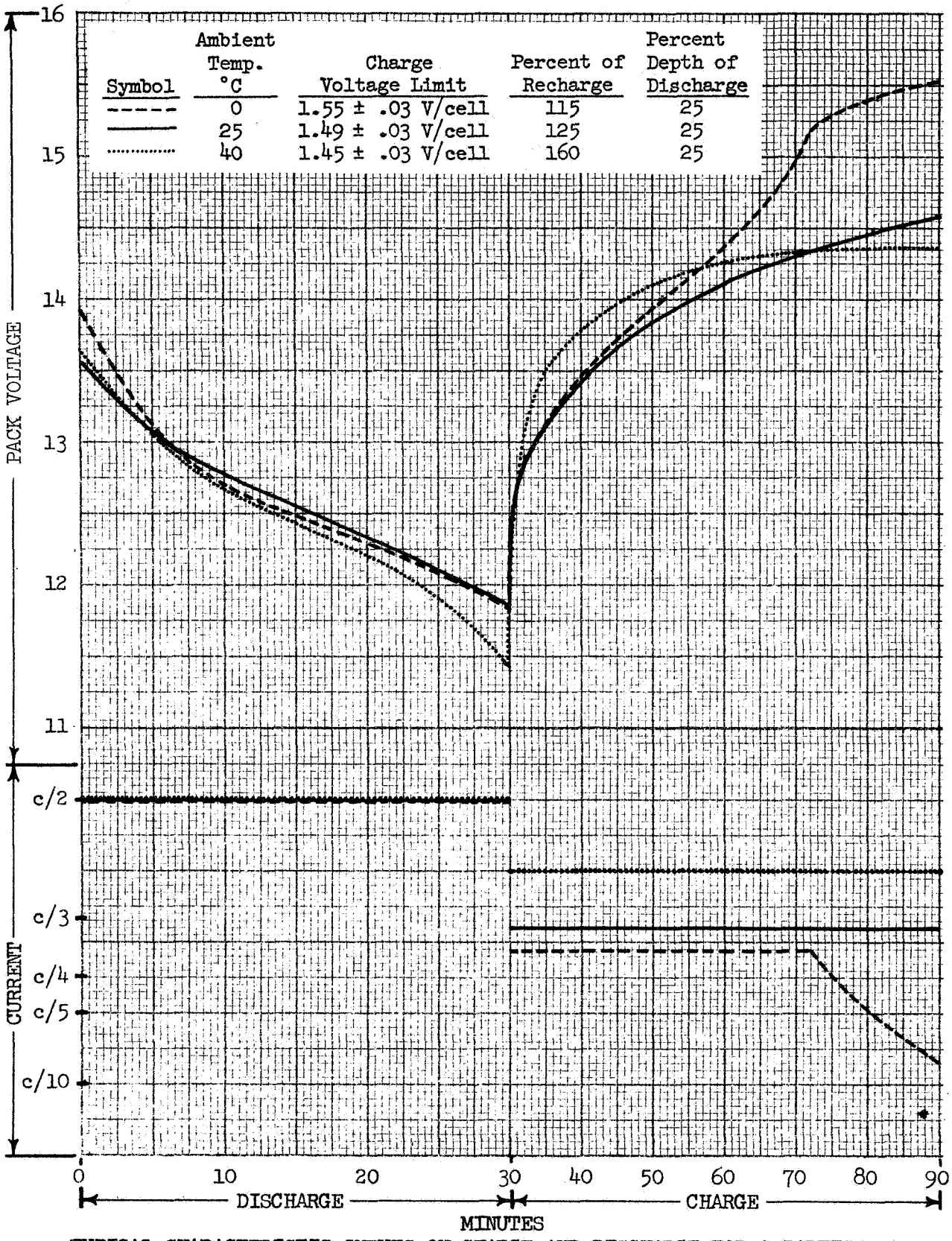
$$= \frac{(0.02 \times 15 \times 3) \times 0.5 \times 1.15}{1}$$

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

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 were cycled 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 were cycled 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 were cycled 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 were cycled 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 were cycled in the vertical position.

d. Sonotone:

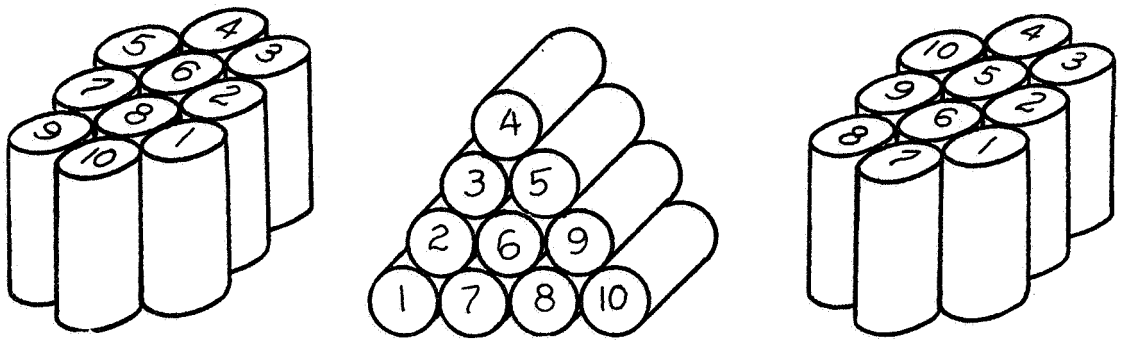
(1) 5.0 Ampere-hour (10-cell Pack): Each cell was wrapped in a double layer of 0.003 inch polyethylene sheet and arranged into oval shaped packs held together with tape, according to diagram (c) of Figure 2. The electrical leads were soldered to the terminals on the tops of the cells. The cells were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

2. Temperature Monitoring:

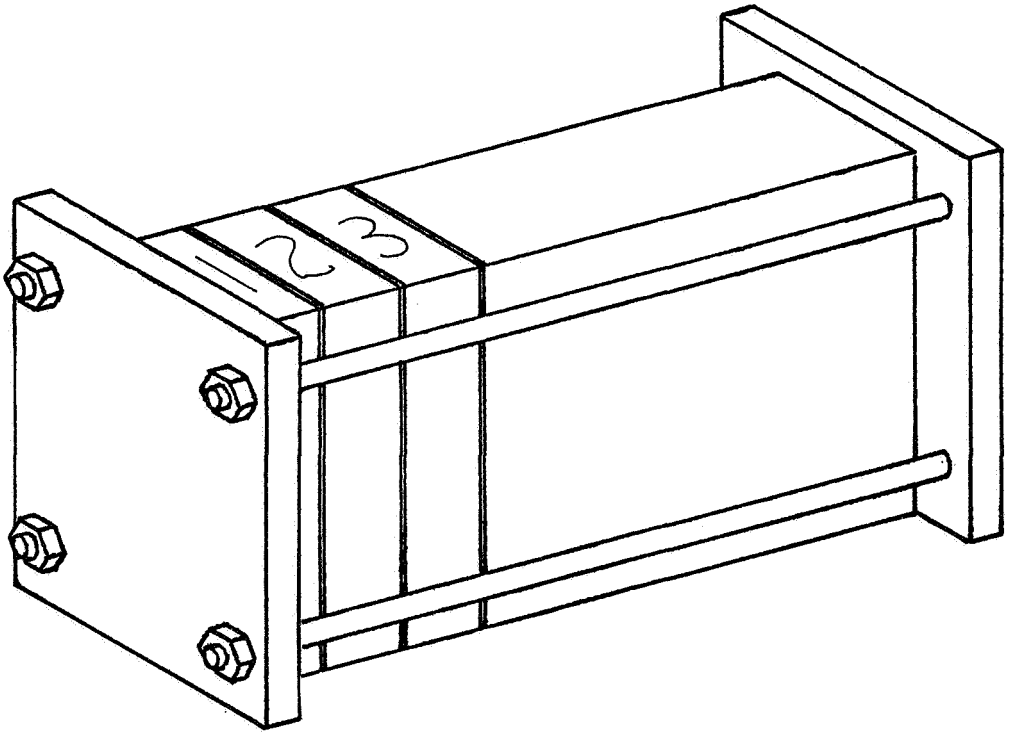
a. A thermocouple (Iron-Constantan, type J) was soldered to the positive terminal of each cell under test.

(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 seven track, one-half inch magnetic tape according to pack and cycle number.

G. Measurements of Ampere-hour Capacity.

1. Precycling Capacity Checks:

a. Prior to start of the cycling program, all packs were precycled 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, as directed by the manufacturer, 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 11(A) through 11(G).

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

2. Precycling 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 precycled 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 precycling 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 Tables 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.

III. TEST RESULTS

A. Current Status:

1. Packs Still Cycling:

a. The number of cycles completed as of 15 December 1968 by the five packs still cycling 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 1655 days to 1722 days.

2. Packs Cycled to Failure:

a. A total of 59 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. Packs Discontinued:

a. Tests on 20 packs were discontinued January 1968 at the request of Goddard Space Flight Center. This makes room for additional newly developed space cells being procured for evaluation. Further it was felt that continuation of these would not provide significant data. Five of the best performing packs were continued for life capability determination purposes.

4. Cycles and Days of Cycling Completed as of 15 December 1968:

a. The number of cycles and the number of days of continuous cycling completed by each pack are given in Table III. The symbol "f" following the cycle number indicates failure of the pack at a given cycle; the symbol "d" indicates that the pack was discontinued at that cycle.

TABLE III

CYCLES AND DAYS OF CYCLING COMPLETED AS OF 15 DECEMBER 1968

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	22923d	1433	110A	26485	1655	51A	22364d	1398	84A	22448d	1403	61A	10146f	634	101A	3629f	227	49A	23112d	1445
		3	67A	11532d	1442	111A	13700	1713	55A	11526d	1441	80A	11378d	1422	65A	11208d	1401	102A	11212d	1402	53A	11427d	1428
	25%	1.5	64A	23441d	1465	124A	27060	1691	52A	13728f	858	98A	10641f	665	62A	22779d	1424	115A	2291f	143	50A	22525d	1408
		3	68A	11740d	1468	125A	13772	1722	56A	11897d	1487	94A	11162d	1395	66A	4414f	552	116A	10971d	1371	54A	11331d	1416
25° C	25%	1.5	15A	10382f	649	82A	10878f	680	3A	4751f	297	104A	2980f	186	13A	4021f	251	73A	7763f	485	1A	11745f	734
		3	19A	10768d	1346	83A	13601	1700	7A	4173f	522	105A	5690f	711	17A	2885f	361	74A	1754f	219	5A	11092d	1387
	40%	1.5	16A	5014f	313	96A	4020f	251	4A	3164f	198	118A	2937f	184	14A	2086f	130	87A	627f	39	2A	6671f	417
		3	20A	5410f	676	97A	5002f	625	8A	2494f	312	119A	1793f	224	18A	1550f	194	88A	358f	45	6A	5211f	651
50° - 40° C	15%	1.5	39A	8109f	507	85A	9710f	607	27A	4485f	280	112A	5213f	326	37A	6064f	379	76A	9348f	584	25A	9328f	583
		3	43A	2656f	332	86A	10661f	1333	31A	2517f	315	108A	4273f	534	41A	1689f	211	77A	6032f	754	29A	5975f	747
	25%	1.5	40A	2511f	157	99A	4853f	303	28A	1811f	113	126A	1569f	98	38A	1377f	86	90A	4045f	253	26A	3625f	227
		3	44A	4487f	561	100A	4424f	553	32A	975f	122	122A	983f	123	42A	4133f	517	91A	4480f	560	30A	4141f	518

f failed
d discontinued

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

1. Figures 3(A) through 9(E) show voltage and percent of recharge for the packs that were cycling in 1968. 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 3(A) through 9(E) discharge voltages tend to drop slightly or remain the same over a period of 5 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).

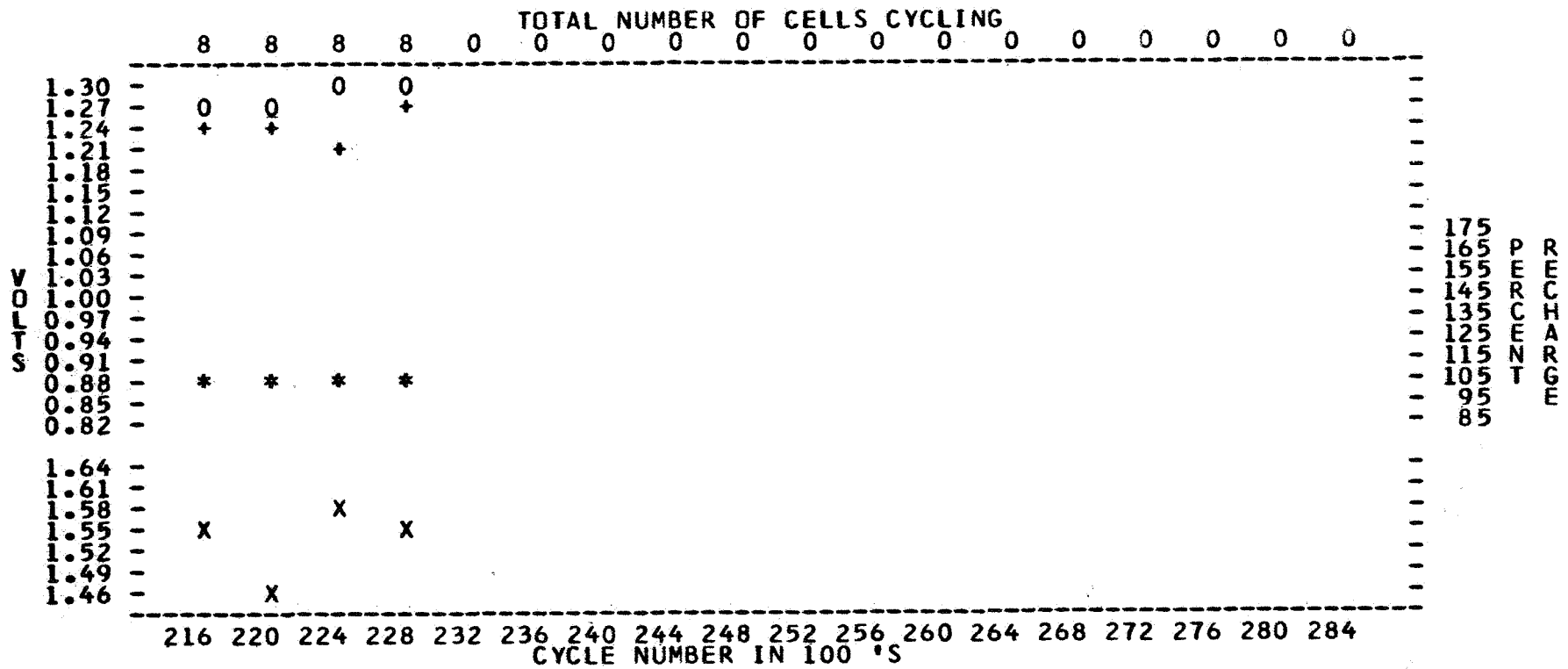
3. The percent of recharge and the end-of-charge voltage must be considered simultaneously since the amount by which the current is reduced during the charge portion of a given cycle is determined by the pack voltage. A tendency towards an increasing end-of-charge voltage will be reflected as a decrease 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 5 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.

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 69-244



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 22923

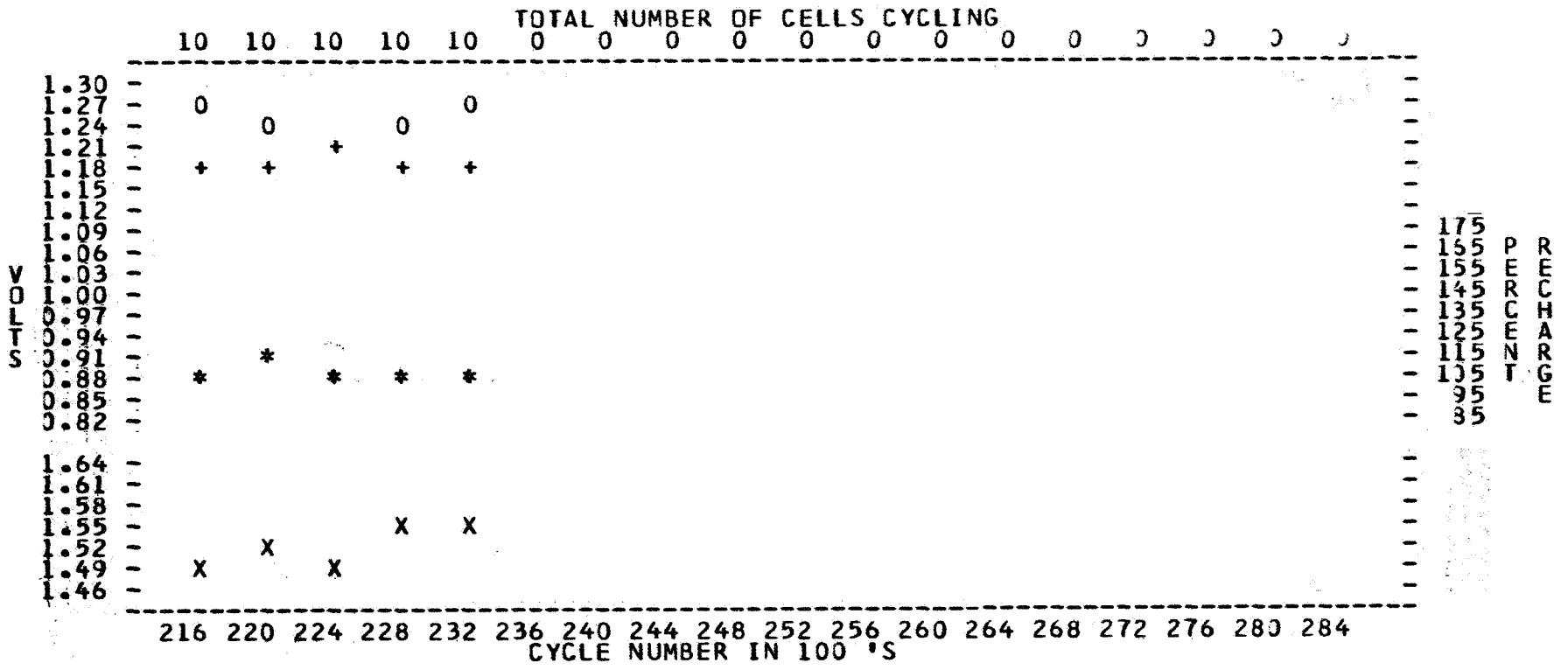
CAPACITY CHECK CYCLES
1546, 2944, 4100, 5607, 7057
8707, 8881, 9835, 11282, 13136
14377, 15908, 17641, 19047, 20225
21455, 22747, 0, 0, 0

PACK DISCONTINUED BY REQUEST OF GODDARD SPACE FLIGHT CENTER.

FIGURE 3(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 69-244



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.

CAPACITY CHECK CYCLES
1442, 2841, 4045, 5472, 7012
8743,10096,11704,13335,14723
16342,18069,19555,20741,22181
23440, 0, 0, 0, 0

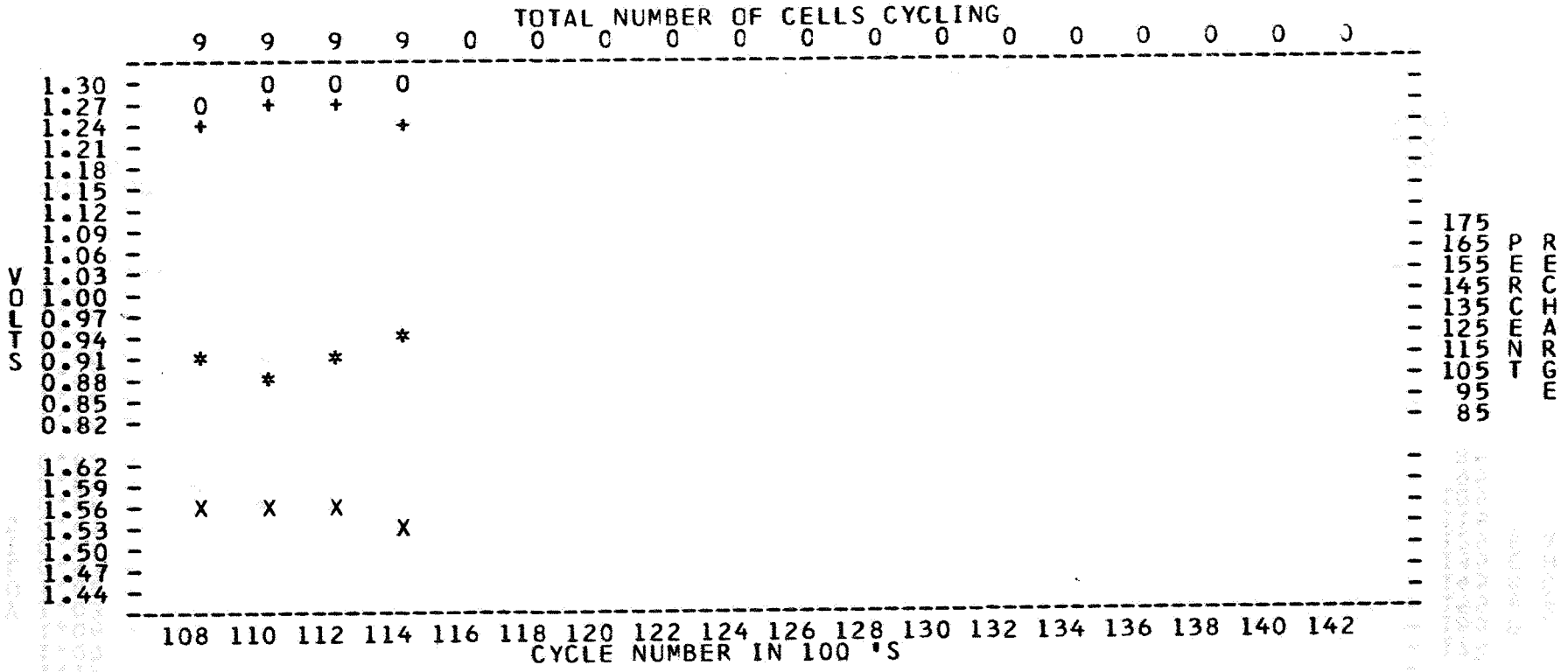
STATUS CELLS CYCLING 10
CYCLES COMPLETED 23441

PACK DISCONTINUED BY REQUEST OF GODDARD SPACE FLIGHT CENTER.

FIGURE 3(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 69-244



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 11532

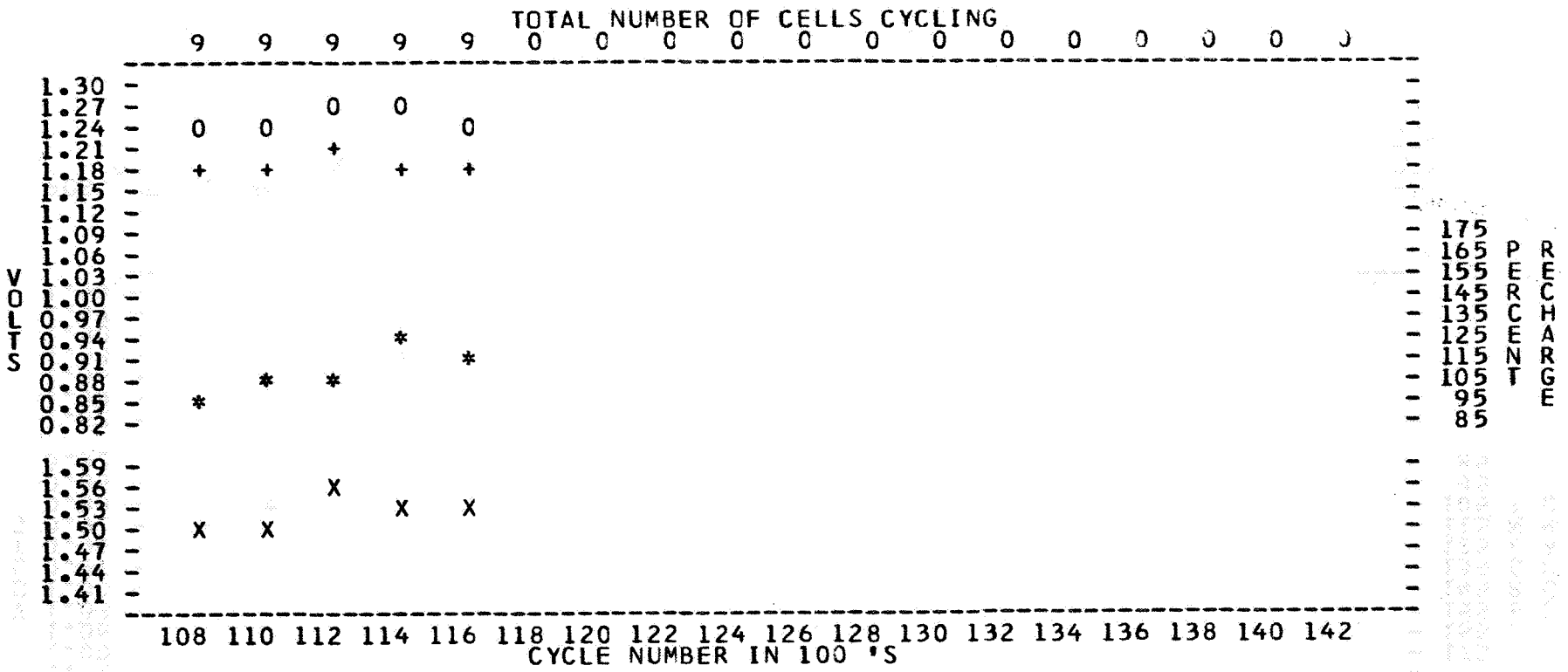
CAPACITY CHECK CYCLES
719, 1374, 2015, 2762, 3504
4271, 4918, 5702, 6508, 7247
8204, 8979, 9682, 10230, 10935
0, 0, 0, 0, 0

PACK DISCONTINUED BY REQUEST OF GODDARD SPACE FLIGHT CENTER.

FIGURE 3(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

GE/C 69-244



POS. NO.	CYCLE FAILED	PACK NUMBER	068A	CAPACITY CHECK CYCLES
09	7054	TYPE OF CELLS	GE 3.00 AH	715, 1431, 2050, 2804, 3508
		TEST TEMPERATURE	00 DEGREES C.	4364, 4956, 5802, 6608, 7166
		ORBIT PERIOD	03.0 HOURS	8103, 9162, 9866,10457,11203
		DEPTH OF DISCHARGE	25 PERCENT	0, 0, 0, 0, 0
		SPECIFIED CHARGE RATE	0.34 AMP.	

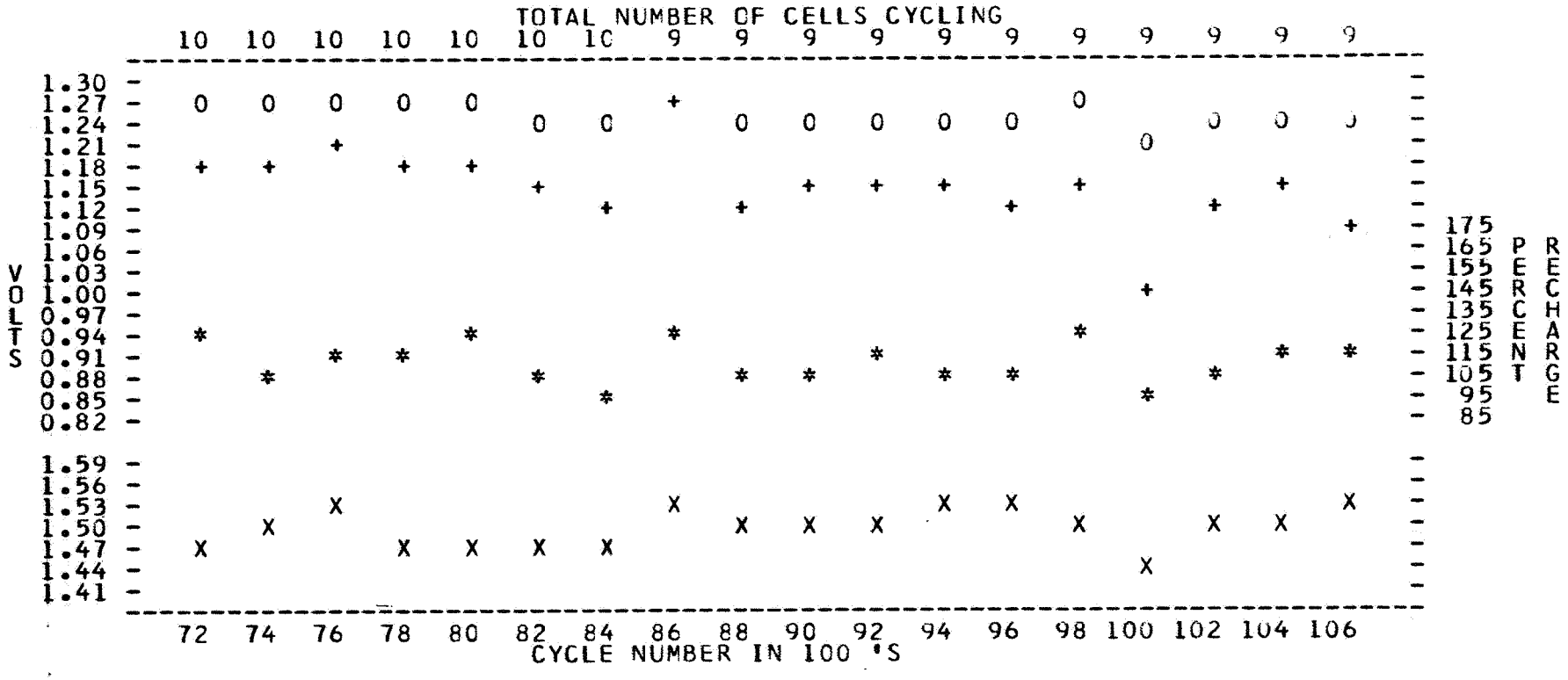
STATUS CELLS CYCLING 9
CYCLES COMPLETED 11740

PACK DISCONTINUED BY REQUEST OF GODDARD SPACE FLIGHT CENTER.

FIGURE 3(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

GE/C 69-244



POS. NO. 01 CYCLE FAILED 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.

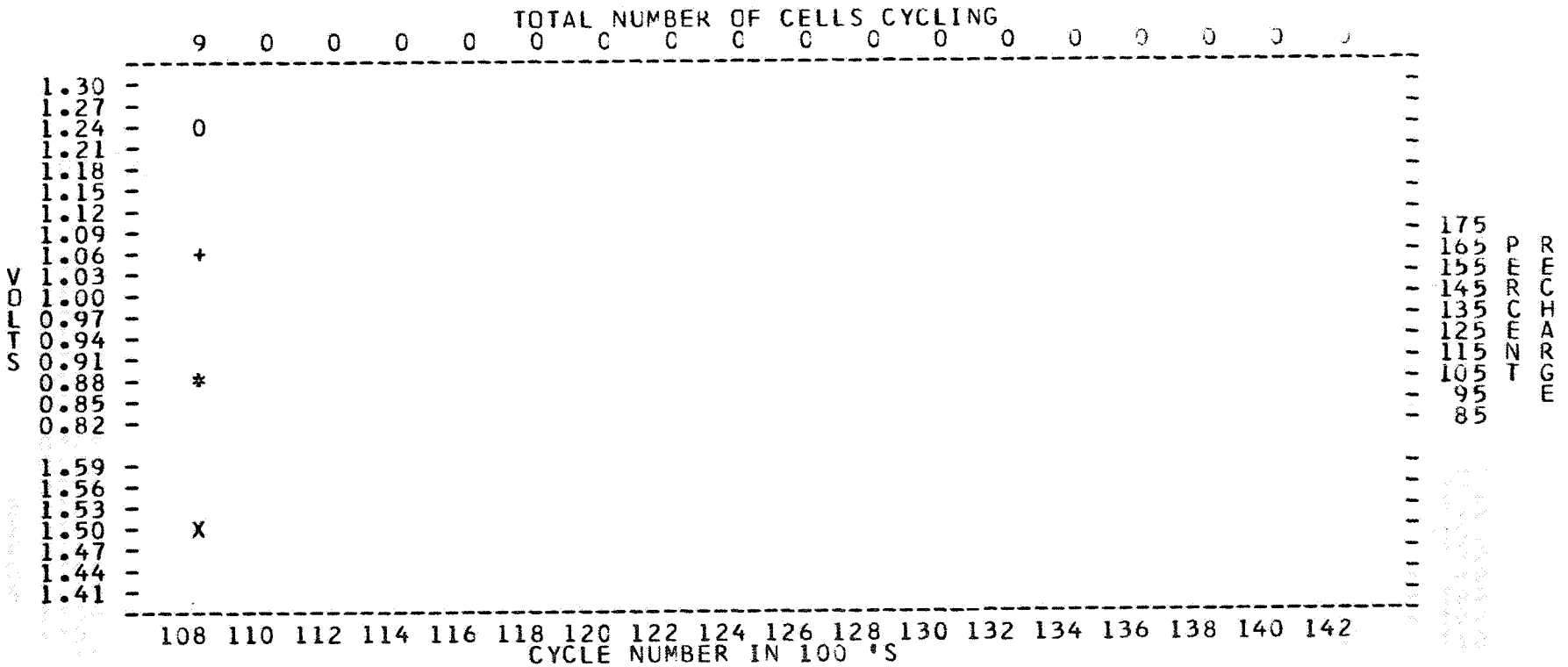
STATUS CELLS CYCLING 9
CYCLES COMPLETED 10768

CAPACITY CHECK CYCLES
674, 1381, 2008, 2722, 3432
4241, 4822, 5607, 6429, 7085
7977, 8590, 9074, 9668, 10111
0, 0, 0, 0, 0

PACK DISCONTINUED BY REQUEST OF GODDARD SPACE FLIGHT CENTER.

FIGURE 3(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



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.

CAPACITY CHECK CYCLES

674, 1381, 2008, 2722, 3432
4241, 4822, 5607, 6429, 7085
7977, 8590, 9074, 9668, 10111
0, 0, 0, 0, 0

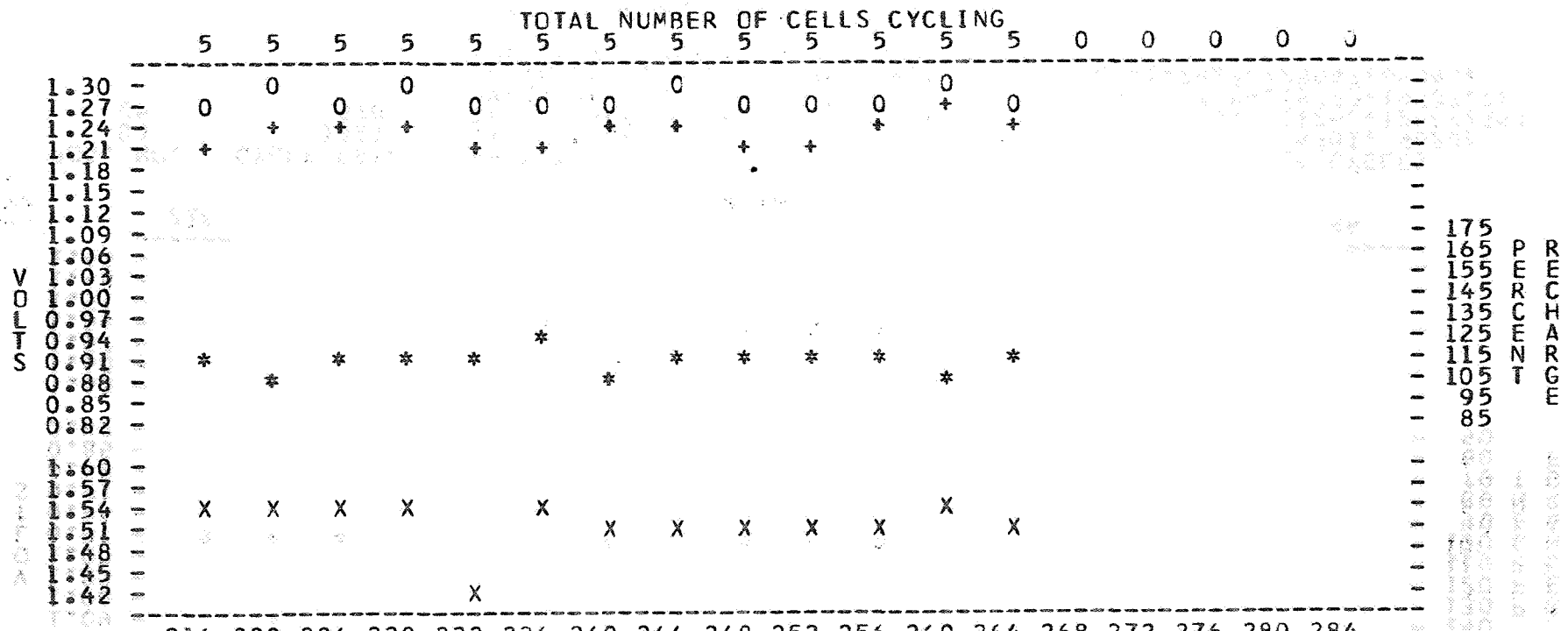
STATUS CELLS CYCLING 9
CYCLES COMPLETED 10768

PACK DISCONTINUED BY REQUEST OF GODDARD SPACE FLIGHT CENTER.

FIGURE 3(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

GE/C 69-244



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.

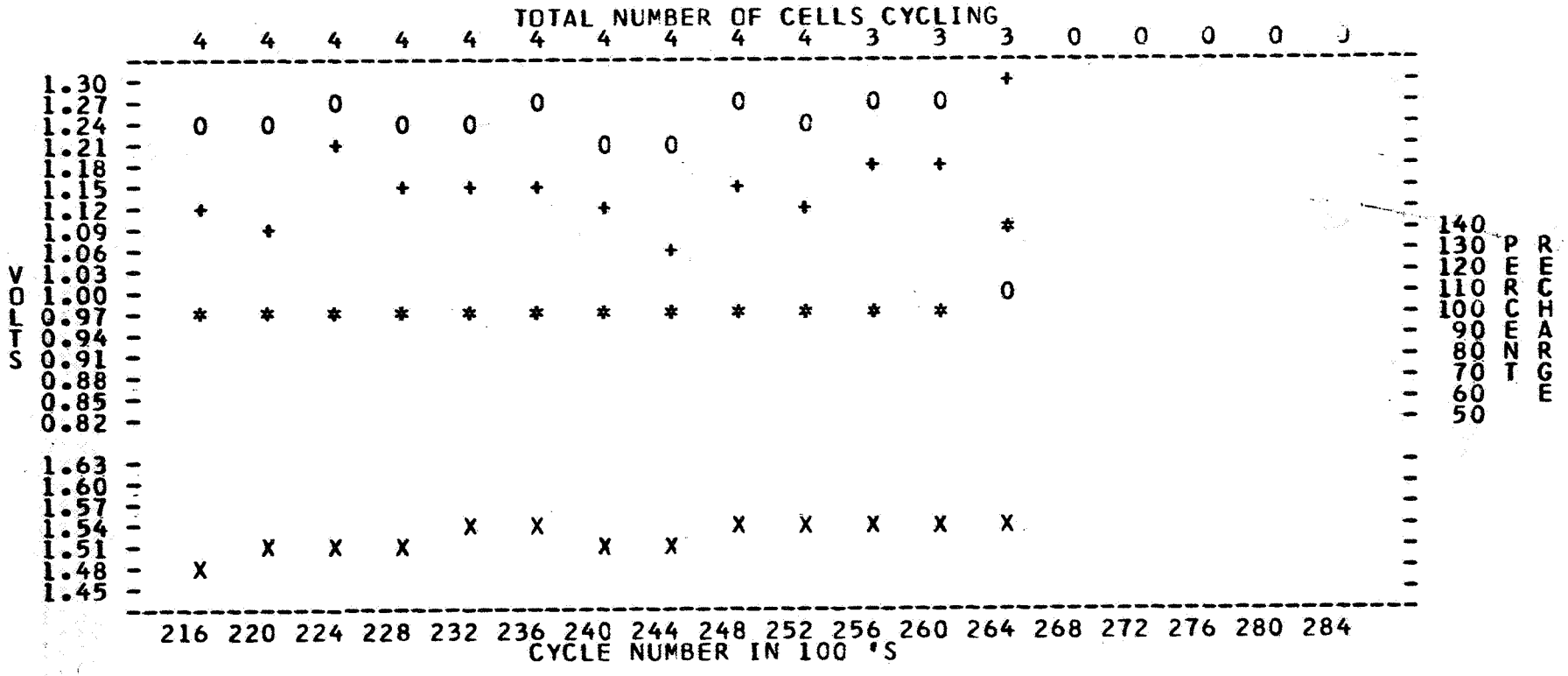
STATUS CELLS CYCLING 5
CYCLES COMPLETED 26485

CAPACITY CHECK CYCLES
1440, 2898, 4410, 5805, 7189
8619, 9777,11495,13095,14556
16288,17727,19021,20204,21691
23112,24200,24522,25995, 0

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

QE/C 69-244



POS. NO.	CYCLE FAILED
03	13218
05	25786

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.

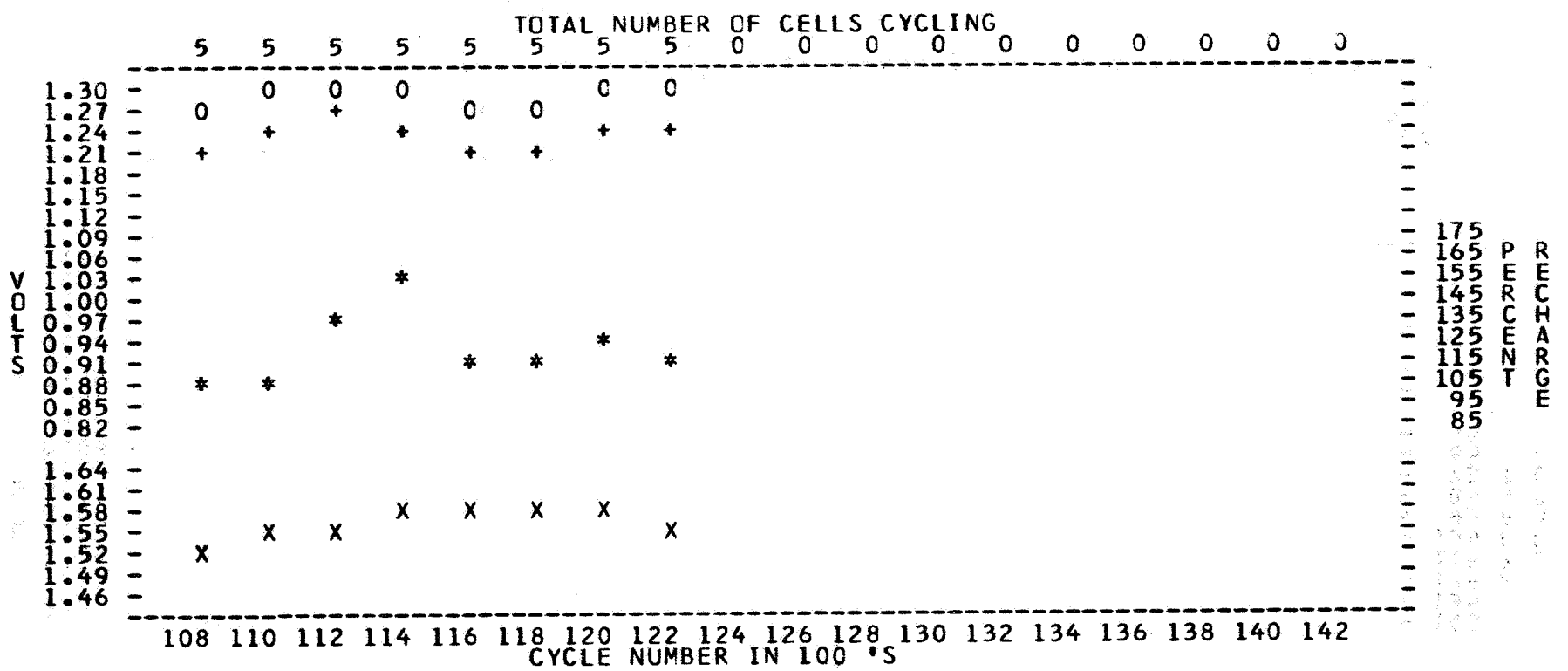
STATUS CELLS CYCLING 4
CYCLES COMPLETED 27060

CAPACITY CHECK CYCLES
1481, 2976, 4301, 5620, 6956
8468, 9544, 11262, 12862, 14182
15915, 17354, 18723, 19907, 21395
22721, 24238, 25647, 26940, 0

FIGURE 4(B)

QE/C 69-244

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

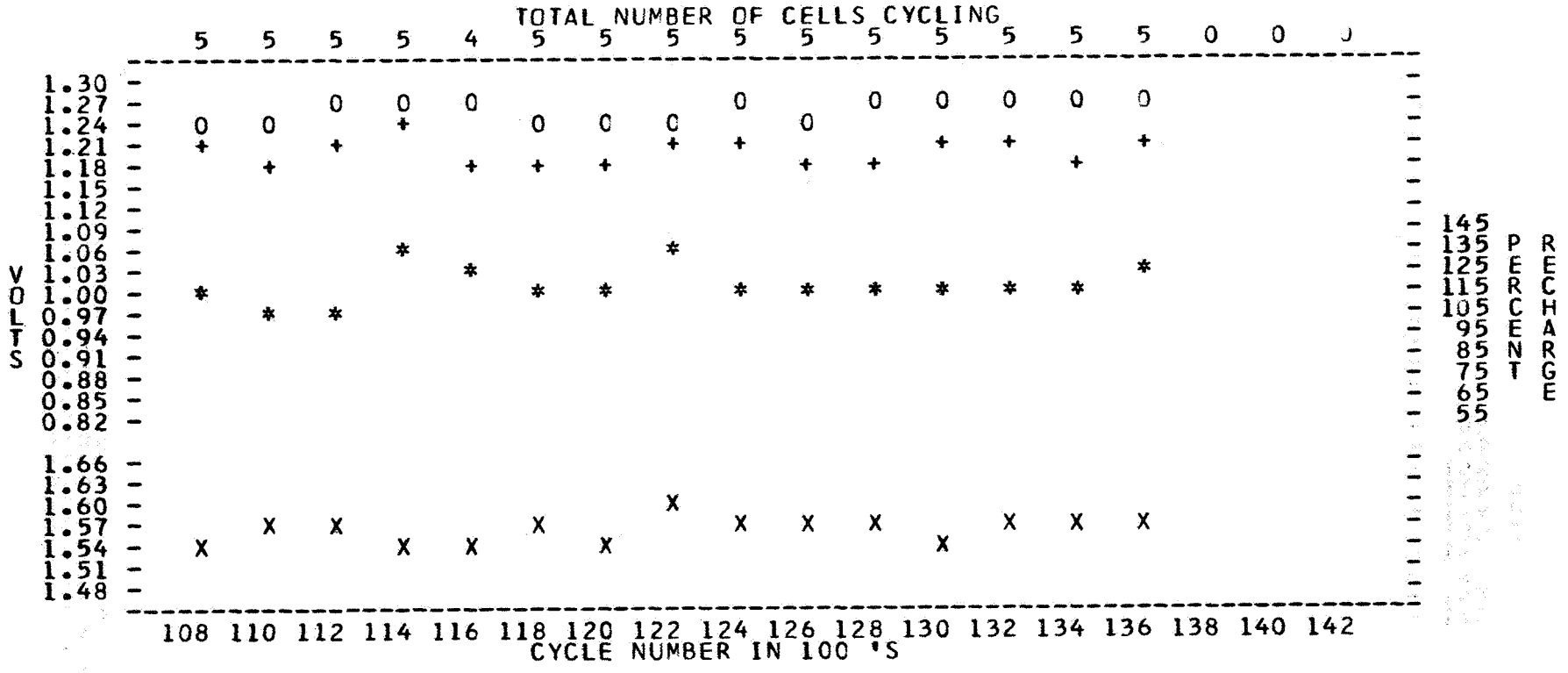
PACK NUMBER 111A
TYPE OF CELLS GE 12.00 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 03.0 HOURS
DEPTH OF DISCHARGE 15 PERCENT
SPECIFIED CHARGE RATE 0.83 AMP.

STATUS CELLS CYCLING 5
CYCLES COMPLETED 13700

CAPACITY CHECK CYCLES
696, 1533, 2179, 2871, 3558
4302, 4884, 5750, 6469, 7188
8100, 8789, 9509,10198,10847
11511,12295,13023, 0, 0

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



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.

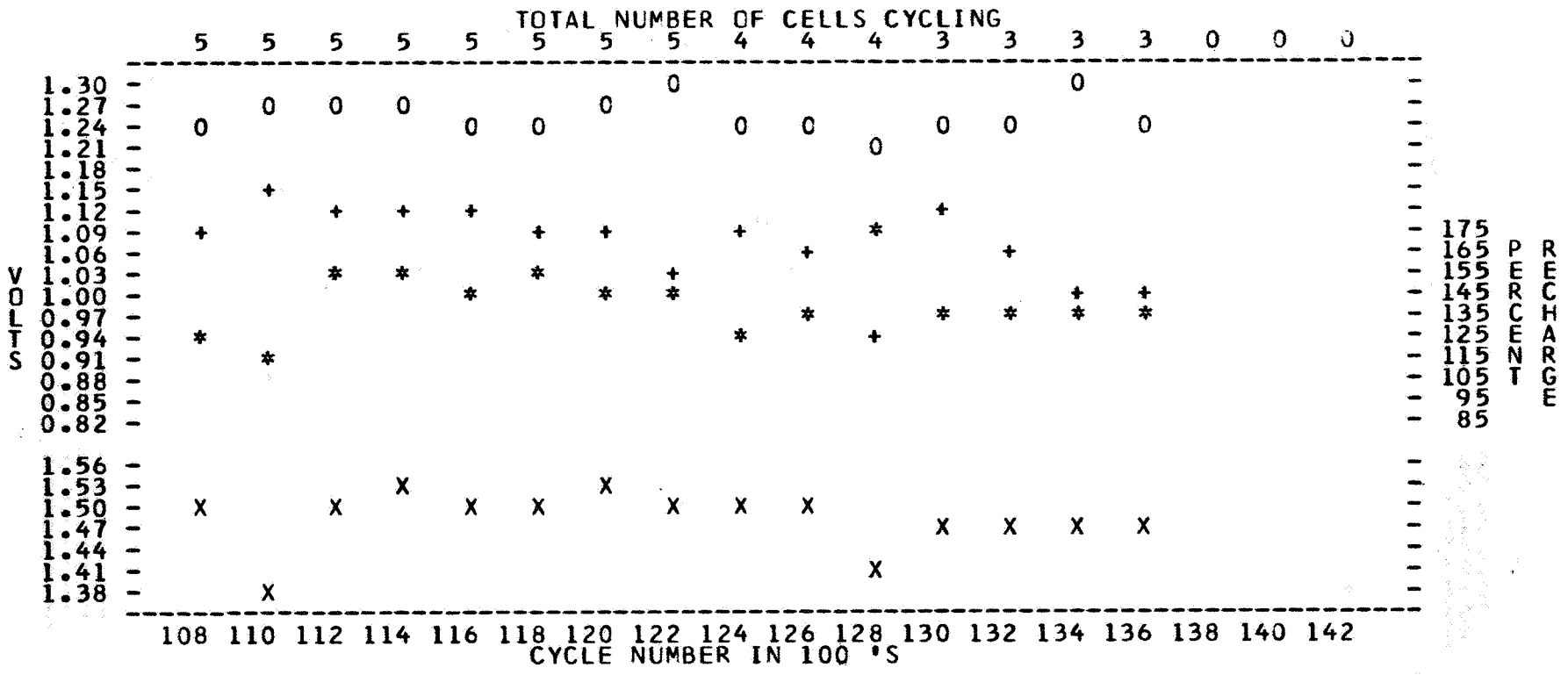
STATUS CELLS CYCLING 5
CYCLES COMPLETED 13772

CAPACITY CHECK CYCLES
695, 1533, 2178, 2870, 3532
4343, 4877, 5743, 6443, 7193
8172, 8861, 9581,10270,10919
11583,12367,13095, 0, 0

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

QE/C 69-244



POS. NO.	CYCLE FAILED
03	12316
04	12822

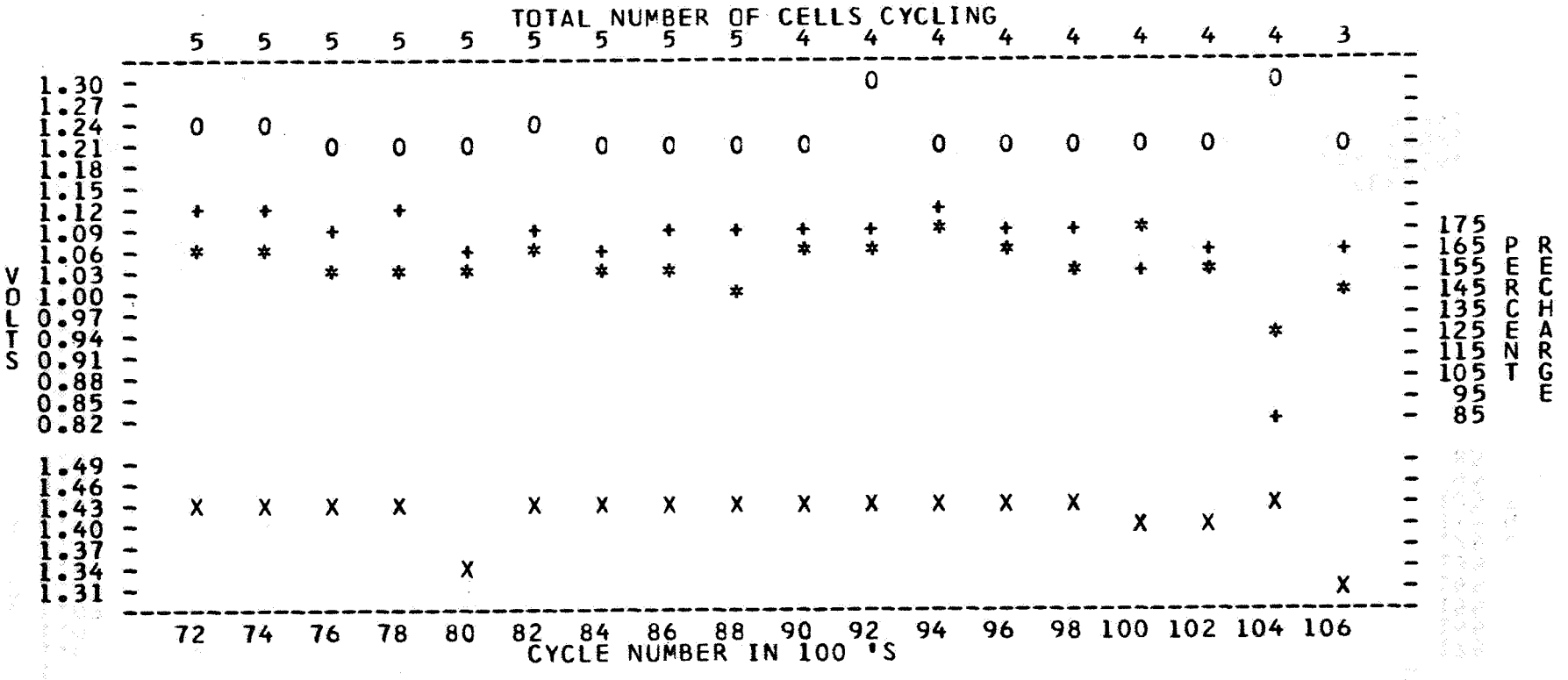
PACK NUMBER 083A
TYPE OF CELLS GE 12.00 AH
TEST TEMPERATURE 25 DEGREES C.
ORBIT PERIOD 03.0 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 1.50 AMP.

STATUS CELLS CYCLING 3
CYCLES COMPLETED 13601

CAPACITY CHECK CYCLES
693, 1362, 2155, 2816, 3496
4362, 4923, 5740, 6502, 7185
8143, 8491, 9542,10134,10878
11542,12287,12924, 0, 0

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



POS. NO.	CYCLE FAILED
03	8988
05	10575
04	10661

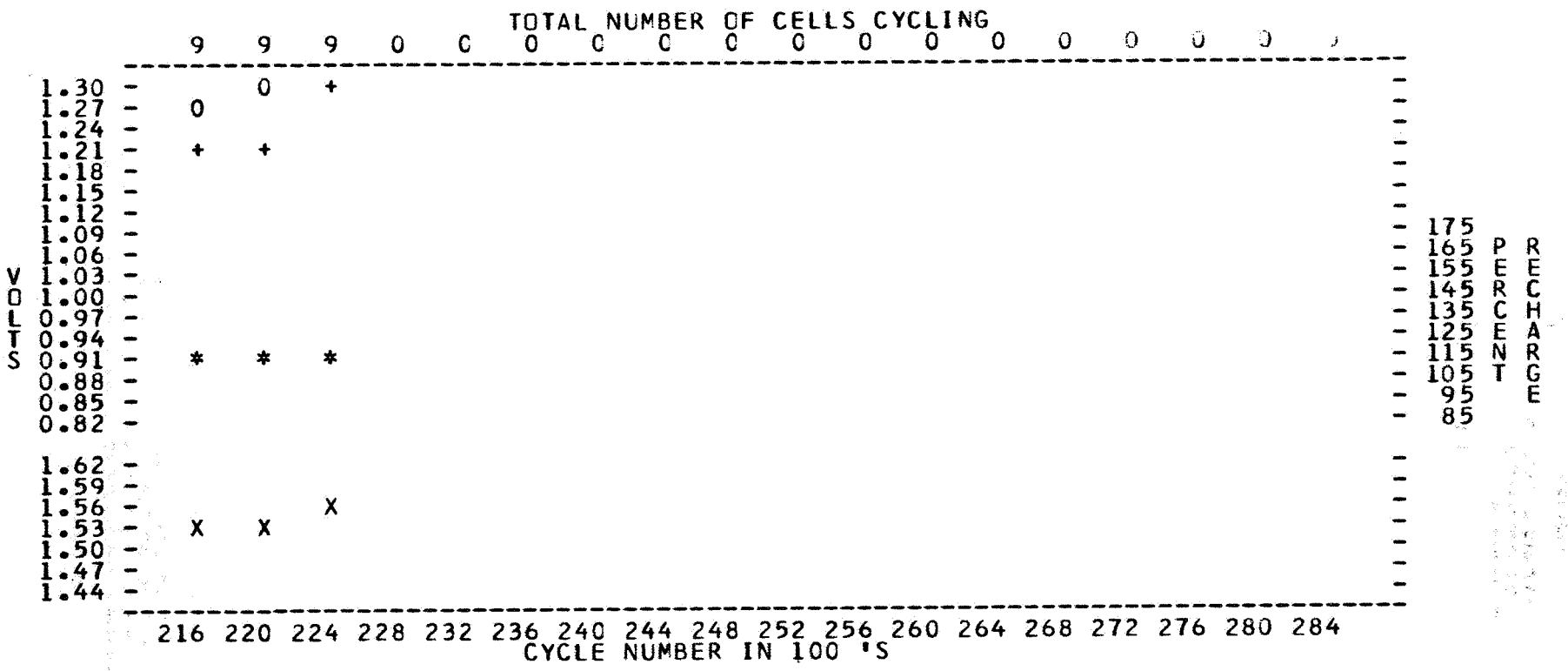
PACK NUMBER 086A
TYPE OF CELLS GE 12.00 AH
TEST TEMPERATURE 40 DEGREES C.
ORBIT PERIOD 03.0 HOURS
DEPTH OF DISCHARGE 15 PERCENT
SPECIFIED CHARGE RATE 1.15 AMP.

STATUS PACK FAILED
ON CYCLE NUMBER 10661

CAPACITY CHECK CYCLES
682, 1519, 2213, 2971, 3670
4372, 4823, 5654, 6419, 6909
7735, 8547, 9092, 9701, 10390
0, 0, 0, 0, 0

FIGURE 4(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



POS. NO.	CYCLE FAILED	PACK NUMBER	051A
10	14737	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.

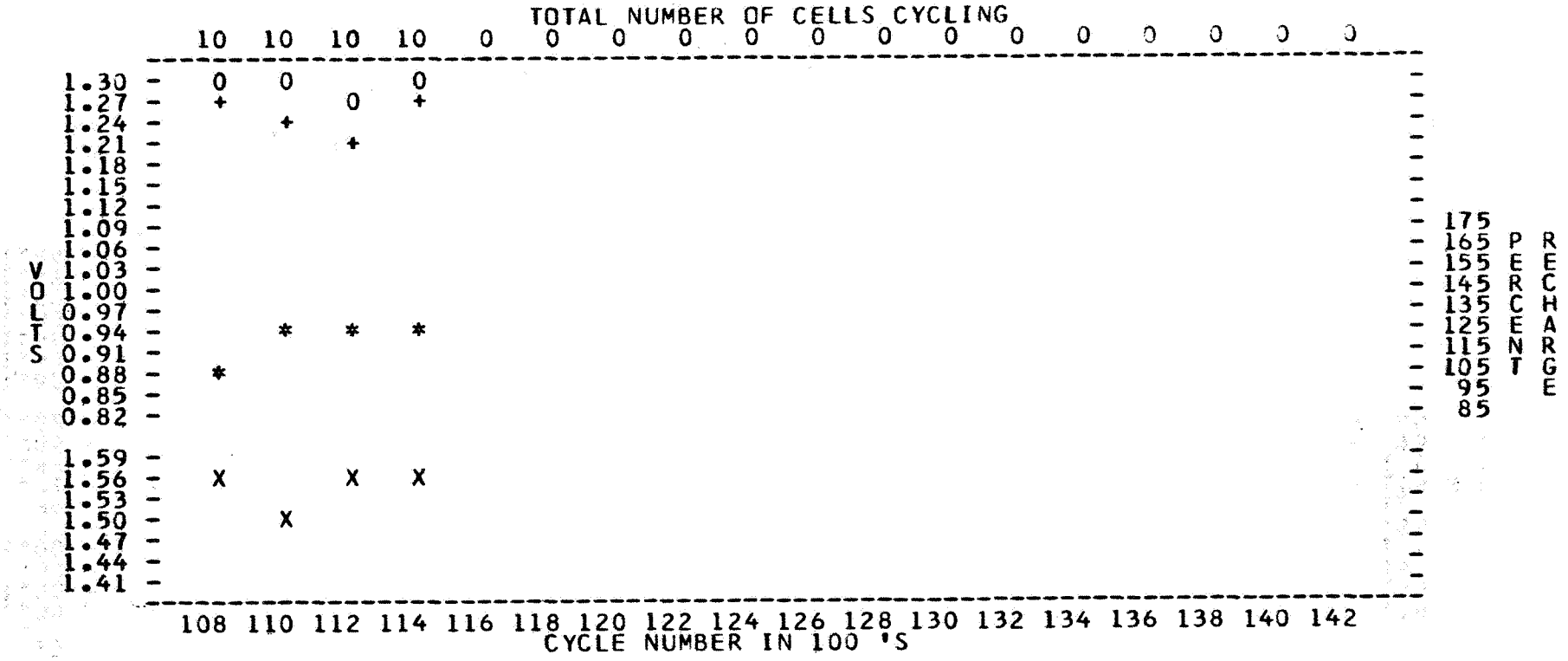
CAPACITY CHECK CYCLES
1546, 2944, 4165, 5565, 7074
8724, 8898, 9852,11299,13153
14347,16067,17800,19206,20221
20896,22188, 0, 0, 0

STATUS CELLS CYCLING 9
CYCLES COMPLETED 22364

PACK DISCONTINUED BY REQUEST OF GODDARD SPACE FLIGHT CENTER.

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



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 11546

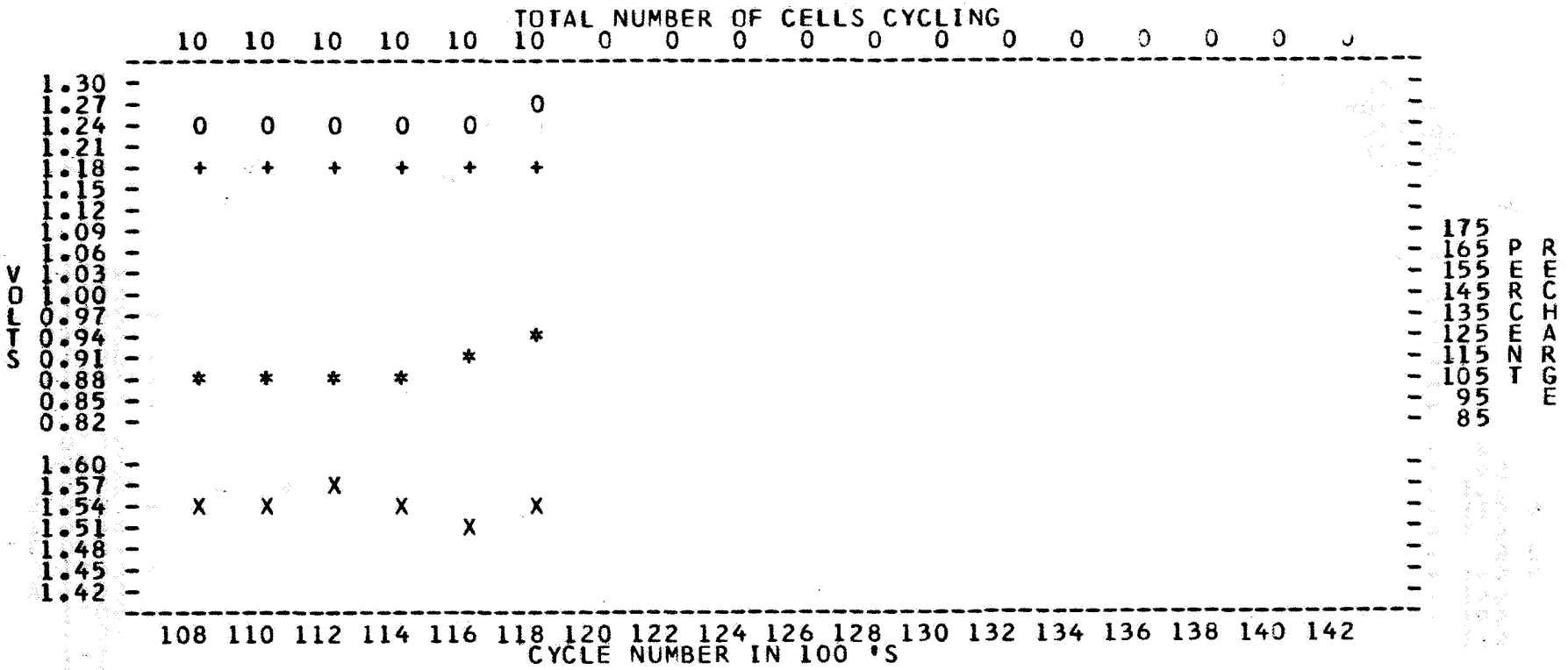
CAPACITY CHECK CYCLES
719, 1374, 2015, 2762, 3504
4301, 4949, 5754, 6560, 7298
8255, 8980, 9683,10275,10995
0, 0, 0, 0, 0

PACK DISCONTINUED BY REQUEST OF GODDARD SPACE FLIGHT CENTER.

FIGURE 5(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 69-244

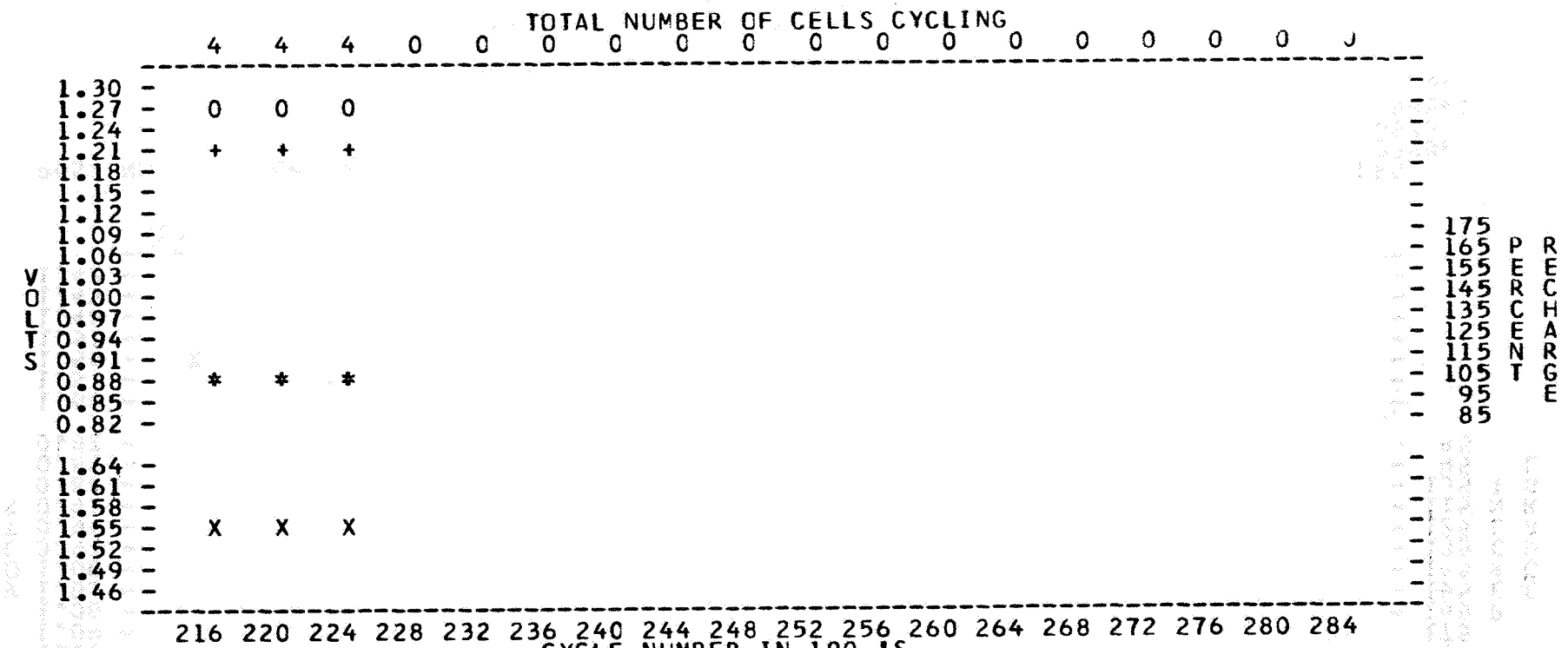


POS. NO.	CYCLE FAILED	PACK NUMBER	056A	CAPACITY CHECK CYCLES
		TYPE OF CELLS	GOULD 3.50 AH	715, 1415, 2034, 2788, 3475
		TEST TEMPERATURE	00 DEGREES C.	4335, 4927, 5765, 6572, 7311
		ORBIT PERIOD	03.0 HOURS	8245, 9304, 10007, 10585, 11290
		DEPTH OF DISCHARGE	25 PERCENT	0, 0, 0, 0, 0
		SPECIFIED CHARGE RATE	0.40 AMP.	
		STATUS	CELLS CYCLING 10	
			CYCLES COMPLETED 11897	

PACK DISCONTINUED BY REQUEST OF GODDARD SPACE FLIGHT CENTER.

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



POS. NO. CYCLE FAILED

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 22448

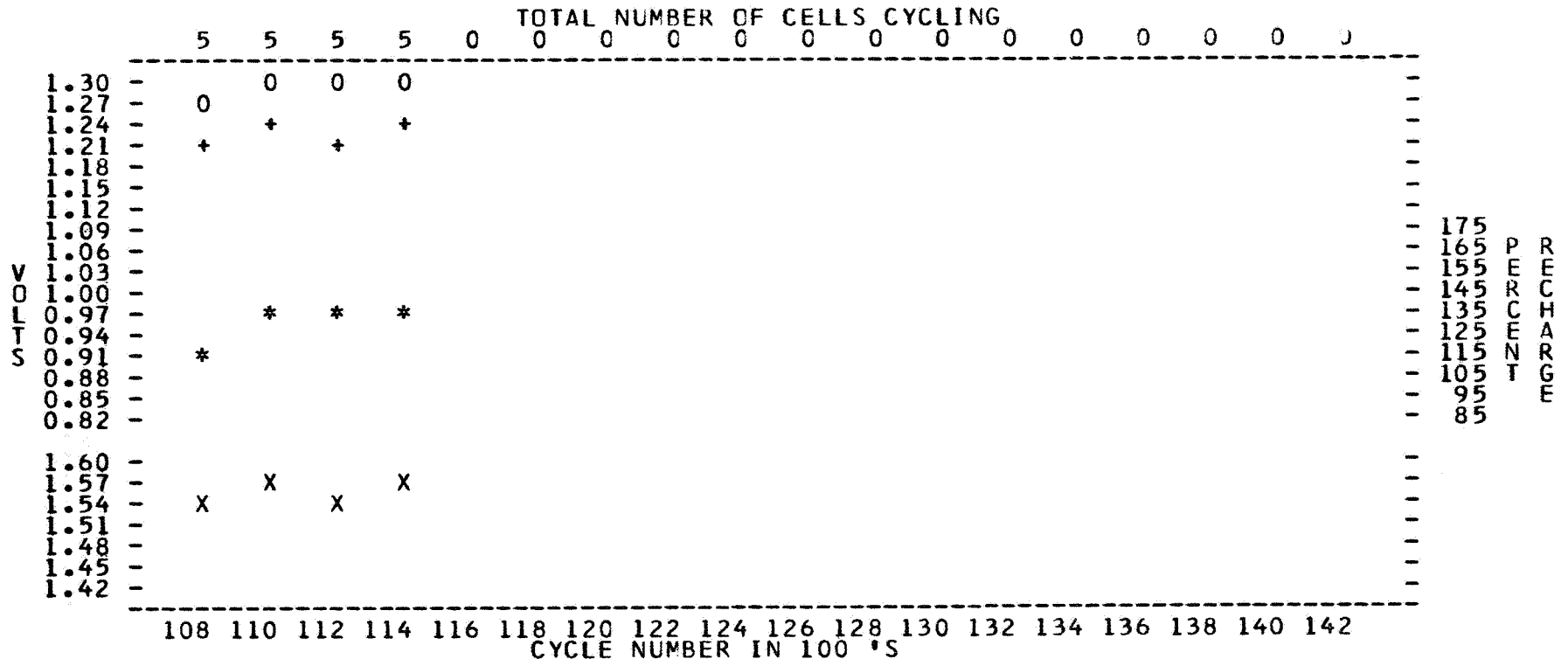
CAPACITY CHECK CYCLES
1471, 3133, 4378, 5848, 7163
8453, 9612,11329,12917,14385
16128,17263,19040,20448,21966
0, 0, 0, 0, 0

PACK DISCONTINUED BY REQUEST OF GODDARD SPACE FLIGHT CENTER.

FIGURE 6(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

GE/C 69-244



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 11378

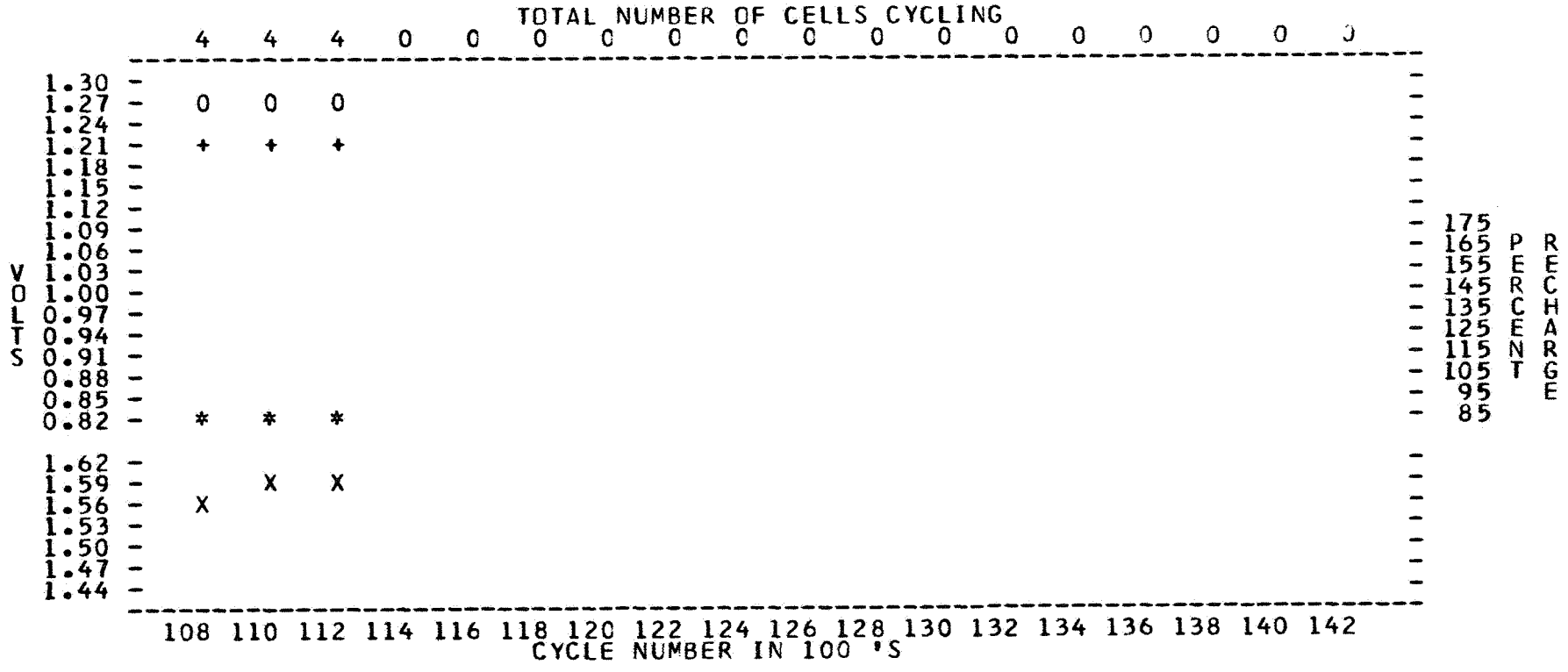
CAPACITY CHECK CYCLES
740, 1611, 2468, 3220, 4031
4536, 5143, 6015, 6668, 7346
8318, 9173, 9839, 10544, 11248
0, 0, 0, 0, 0

PACK DISCONTINUED BY REQUEST OF GODDARD SPACE FLIGHT CENTER.

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

QE/C 69-244



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 4
CYCLES COMPLETED 11162

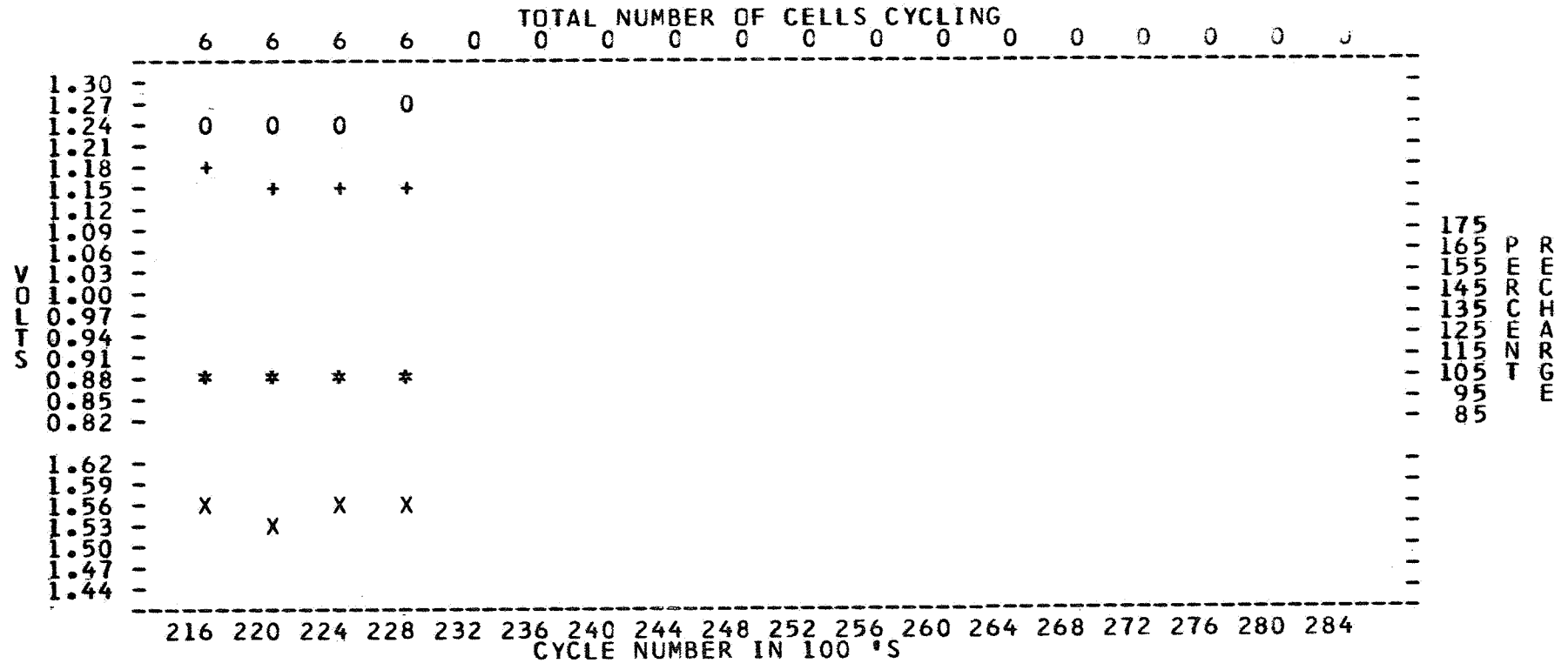
CAPACITY CHECK CYCLES
727, 1506, 2173, 2908, 3605
4352, 4915, 5690, 6496, 7174
8185, 9002, 9495, 10216, 10960
0, 0, 0, 0, 0

PACK DISCONTINUED BY REQUEST OF GODDARD SPACE FLIGHT CENTER.

FIGURE 6(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 69-244



POS. NO.	CYCLE FAILED
10	2995
04	4066
05	4441
07	8590

PACK NUMBER 062A
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 1.72 AMP.

CAPACITY CHECK CYCLES
1386, 2741, 4090, 5647, 7050
8369, 9547, 11620, 12776, 14164
15865, 17508, 18917, 20178, 21617
0, 0, 0, 0, 0

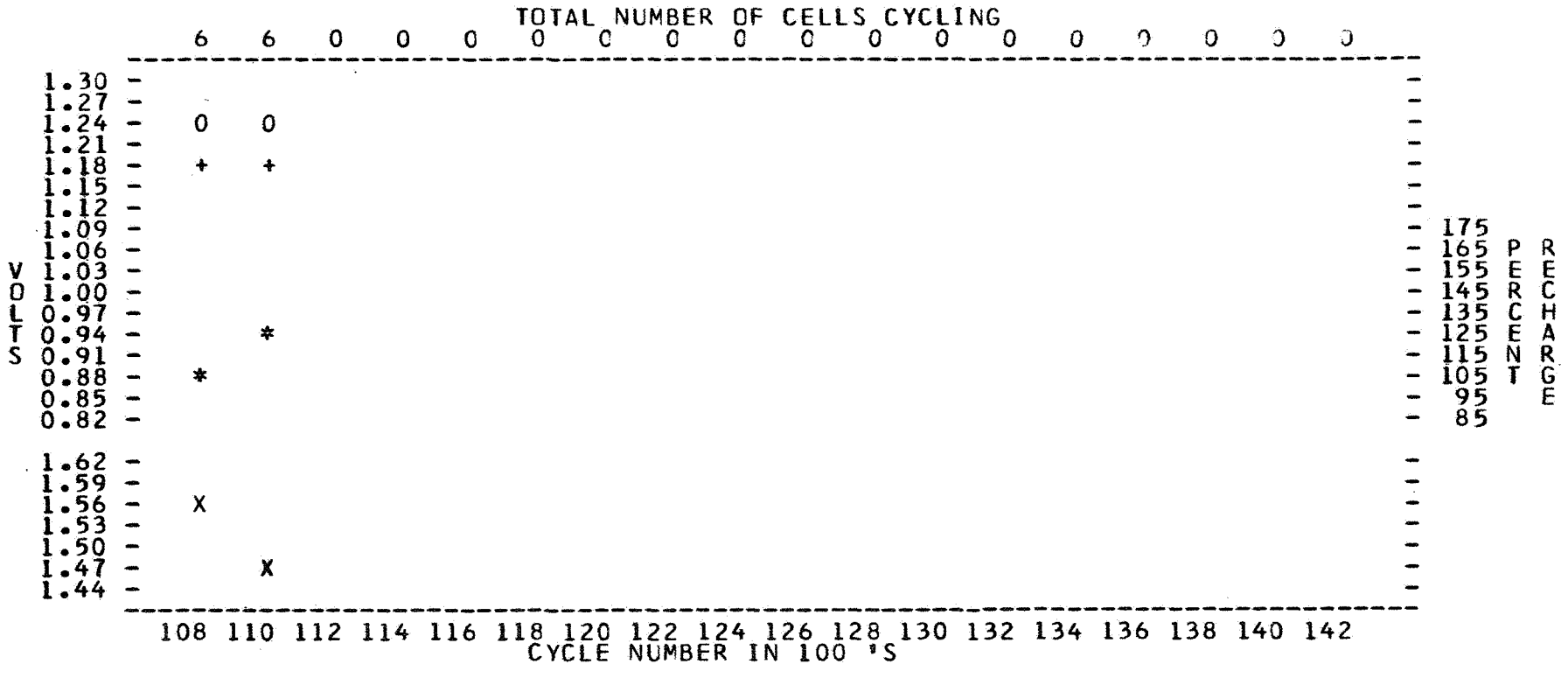
STATUS CELLS CYCLING 6
CYCLES COMPLETED 22779

PACK DISCONTINUED BY REQUEST OF GODDARD SPACE FLIGHT CENTER.

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

QE/C 69-244



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, 6823, 7045
7979, 8724, 9455, 10048, 10783
0, 0, 0, 0, 0

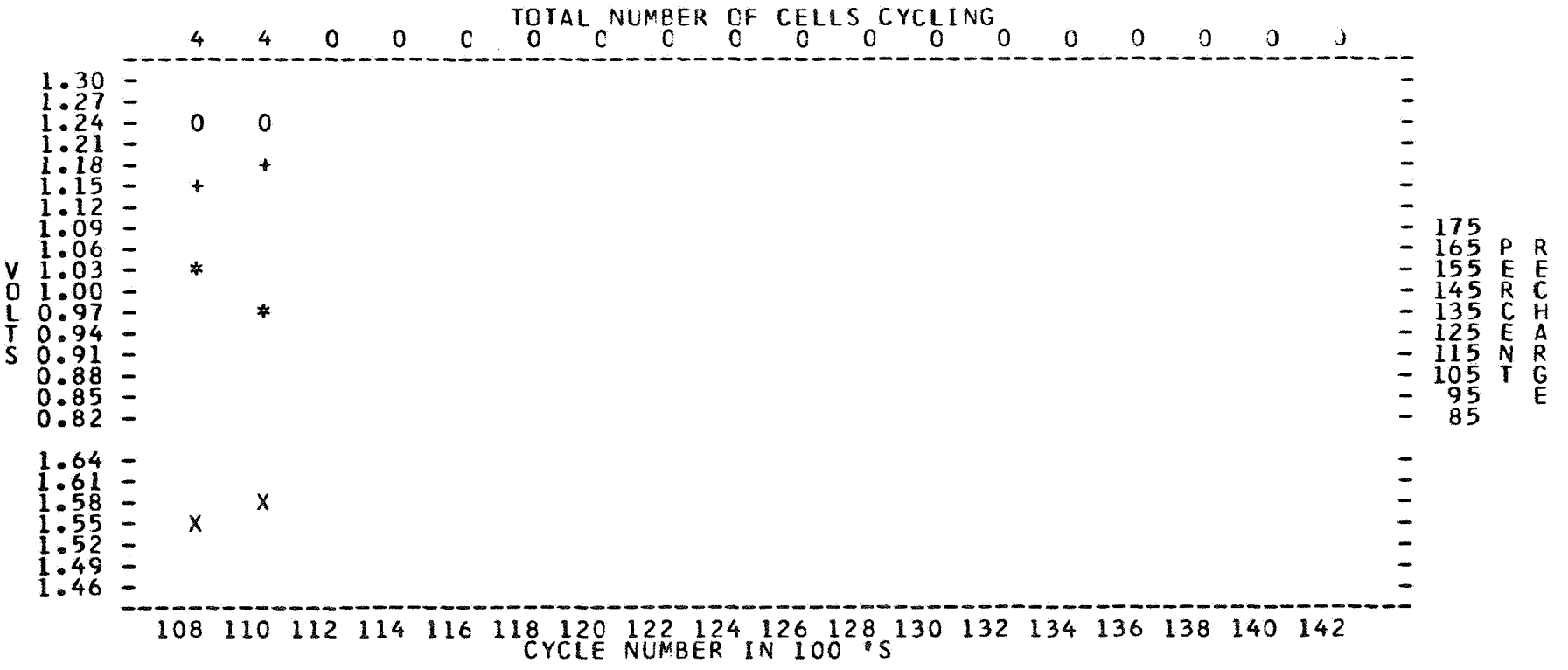
STATUS CELLS CYCLING 6
CYCLES COMPLETED 11208

PACK DISCONTINUED BY REQUEST OF GODDARD SPACE FLIGHT CENTER.

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 69-244



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.

CAPACITY CHECK CYCLES

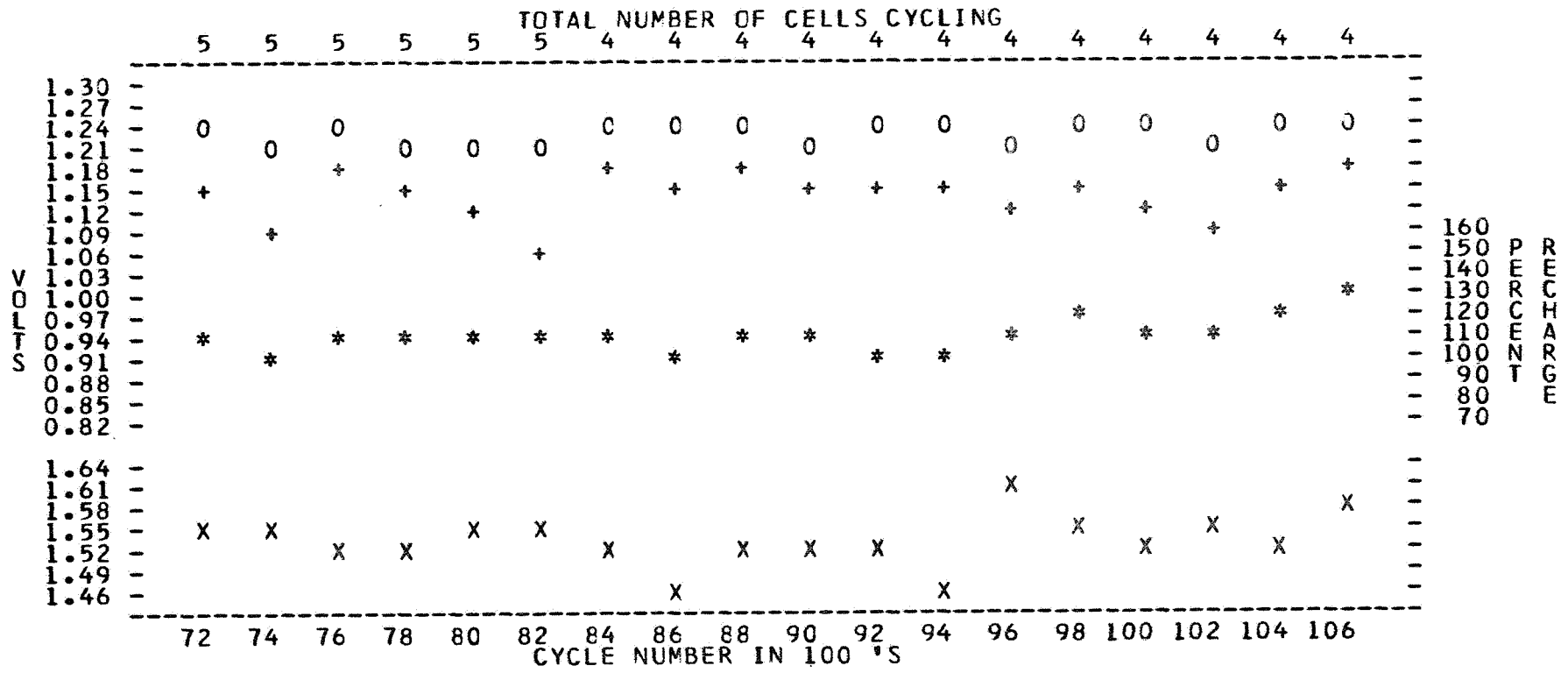
716, 1437, 2104, 2839, 3536
4364, 4971, 5843, 6496, 7174
8153, 9009, 9025, 9674, 10379
11083, 0, 0, 0, 0

STATUS CELLS CYCLING 4
CYCLES COMPLETED 11212

PACK DISCONTINUED BY REQUEST OF GODDARD SPACE FLIGHT CENTER.

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



POS. NO. 03 — CYCLE FAILED 8274

PACK NUMBER 116A
TYPE OF CELLS GULTON 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 4
CYCLES COMPLETED 10971

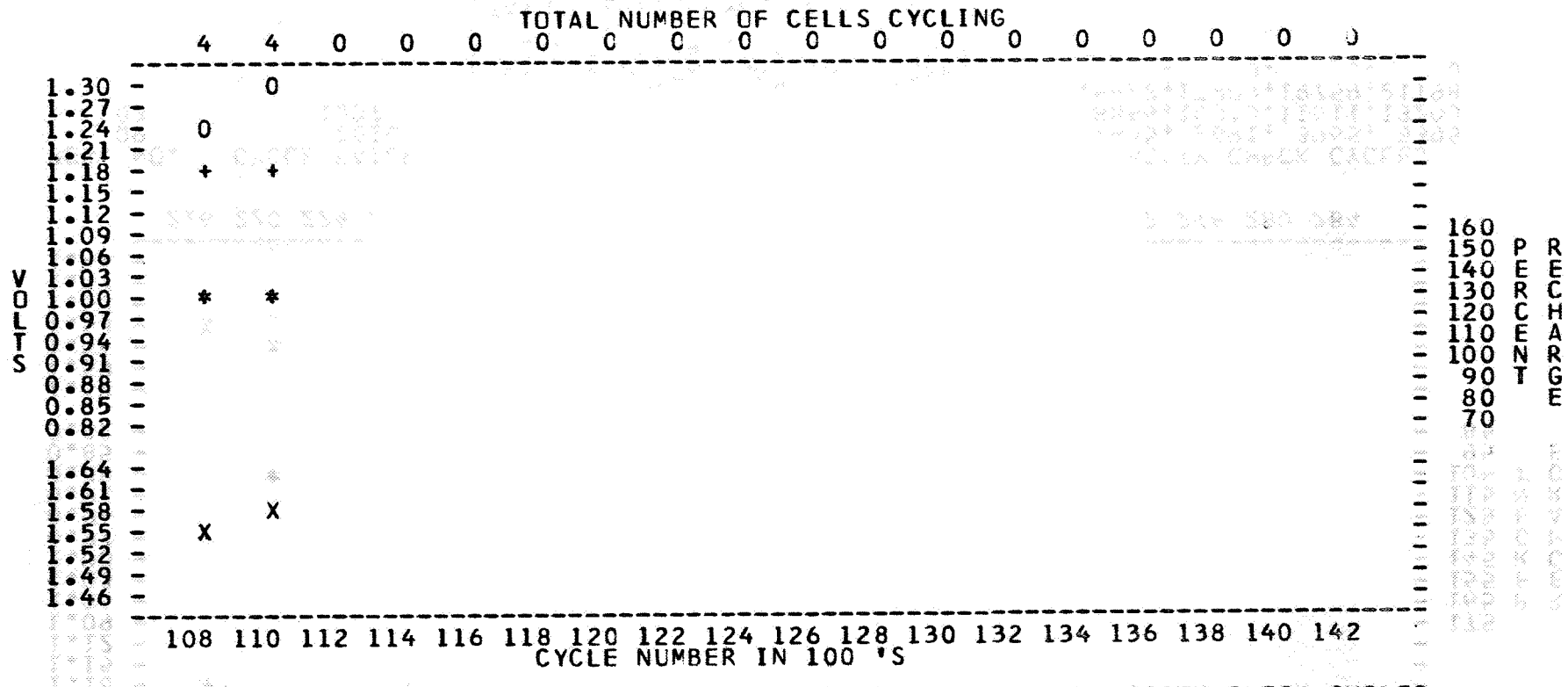
CAPACITY CHECK CYCLES
760, 1357, 2017, 2750, 3393
4147, 4703, 5478, 6284, 6962
7956, 8712, 9305, 10021, 10770
0, 0, 0, 0, 0

PACK DISCONTINUED BY REQUEST OF GODDARD SPACE FLIGHT CENTER.

FIGURE 8(B)

QE/C 69-244

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



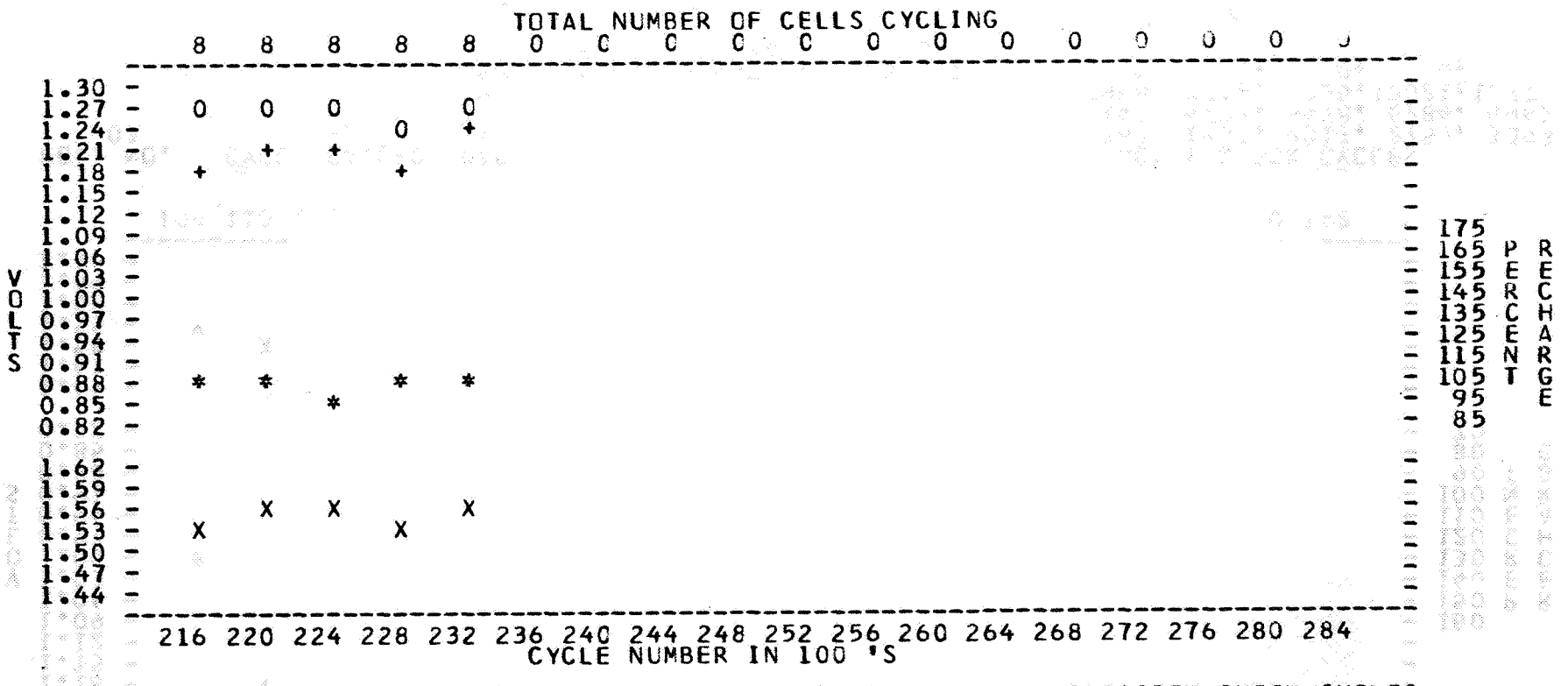
POS. NO.	CYCLE FAILED			CAPACITY CHECK CYCLES
03	8274	PACK NUMBER	116A	760, 1357, 2017, 2750, 3393
		TYPE OF CELLS	GULTON 20.00 AH	4147, 4703, 5478, 6284, 6962
		TEST TEMPERATURE	00 DEGREES C.	7956, 8712, 9305,10021,10770
		ORBIT PERIOD	03.0 HOURS	0, 0, 0, 0, 0
		DEPTH OF DISCHARGE	25 PERCENT	
		SPECIFIED CHARGE RATE	2.30 AMP.	

STATUS CELLS CYCLING 4
CYCLES COMPLETED 10971

PACK DISCONTINUED BY REQUEST OF GODDARD SPACE FLIGHT CENTER.

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



POS. NO.	CYCLE FAILED
09	2010
03	10073

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

STATUS CELLS CYCLING 8
CYCLES COMPLETED 23112

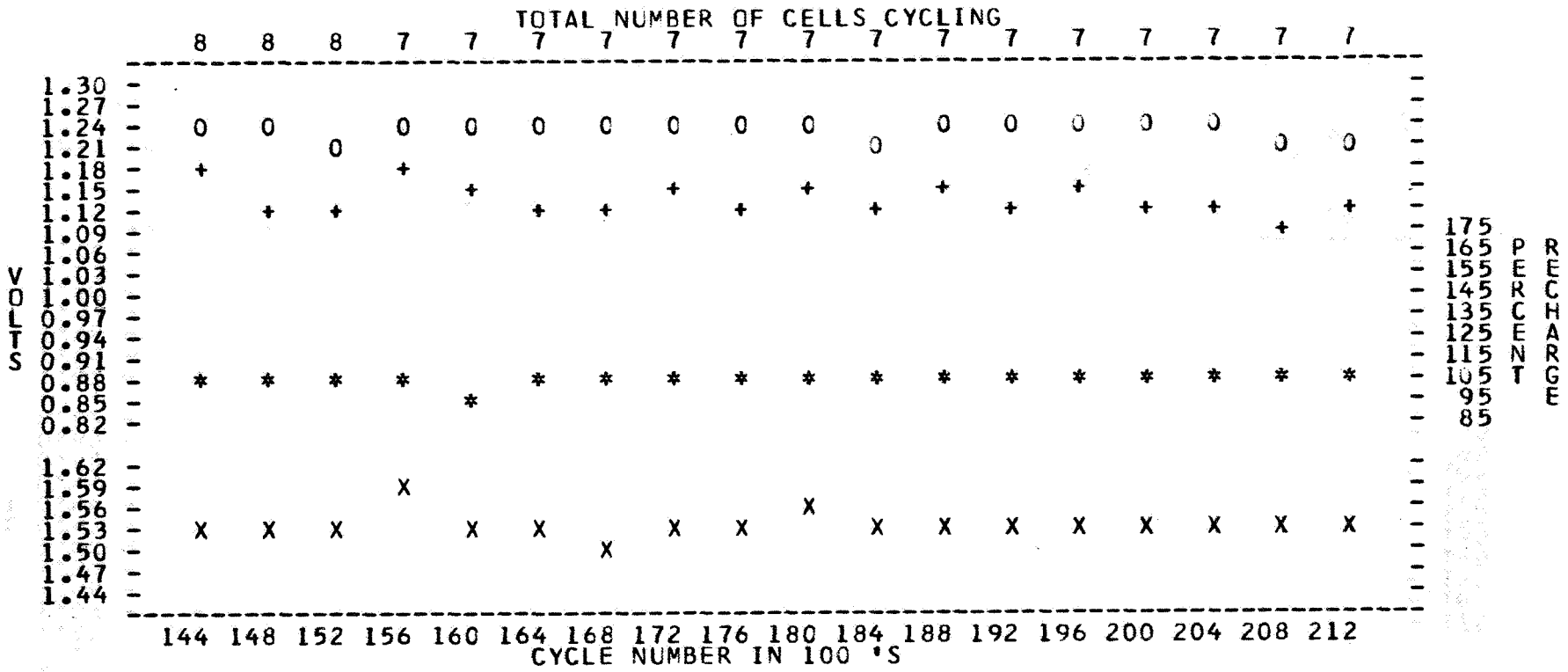
CAPACITY CHECK CYCLES
1405, 2691, 3965, 5395, 6895
8864,10010,11611,13200,14668
16422,17909,19759,21198,22600
0, 0, 0, 0, 0

PACK DISCONTINUED BY REQUEST OF GODDARD SPACE FLIGHT CENTER.

FIGURE 9(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 69-244



POS. NO.	CYCLE FAILED
05	12069
03	13500
04	15294

PACK NUMBER 050A
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 1.44 AMP.

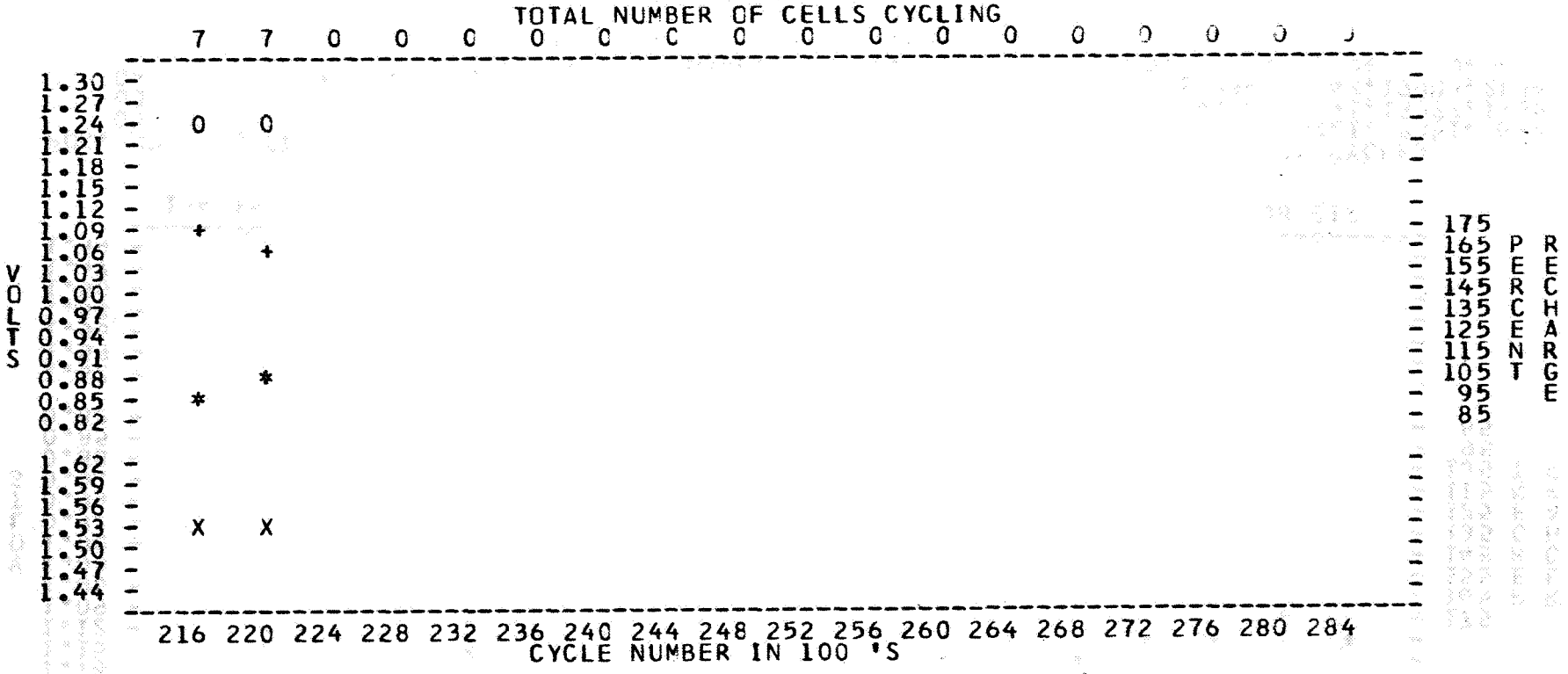
STATUS CELLS CYCLING 7
CYCLES COMPLETED 22525

CAPACITY CHECK CYCLES
1435, 2648, 3921, 5351, 6782
8739, 9978, 11691, 13077, 14382
15591, 17234, 18643, 19903, 21345
0, 0, 0, 0, 0

PACK DISCONTINUED BY REQUEST OF GODDARD SPACE FLIGHT CENTER.

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



POS. NO.	CYCLE FAILED
05	12069
03	13500
04	15294

PACK NUMBER 050A
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 1.44 AMP.

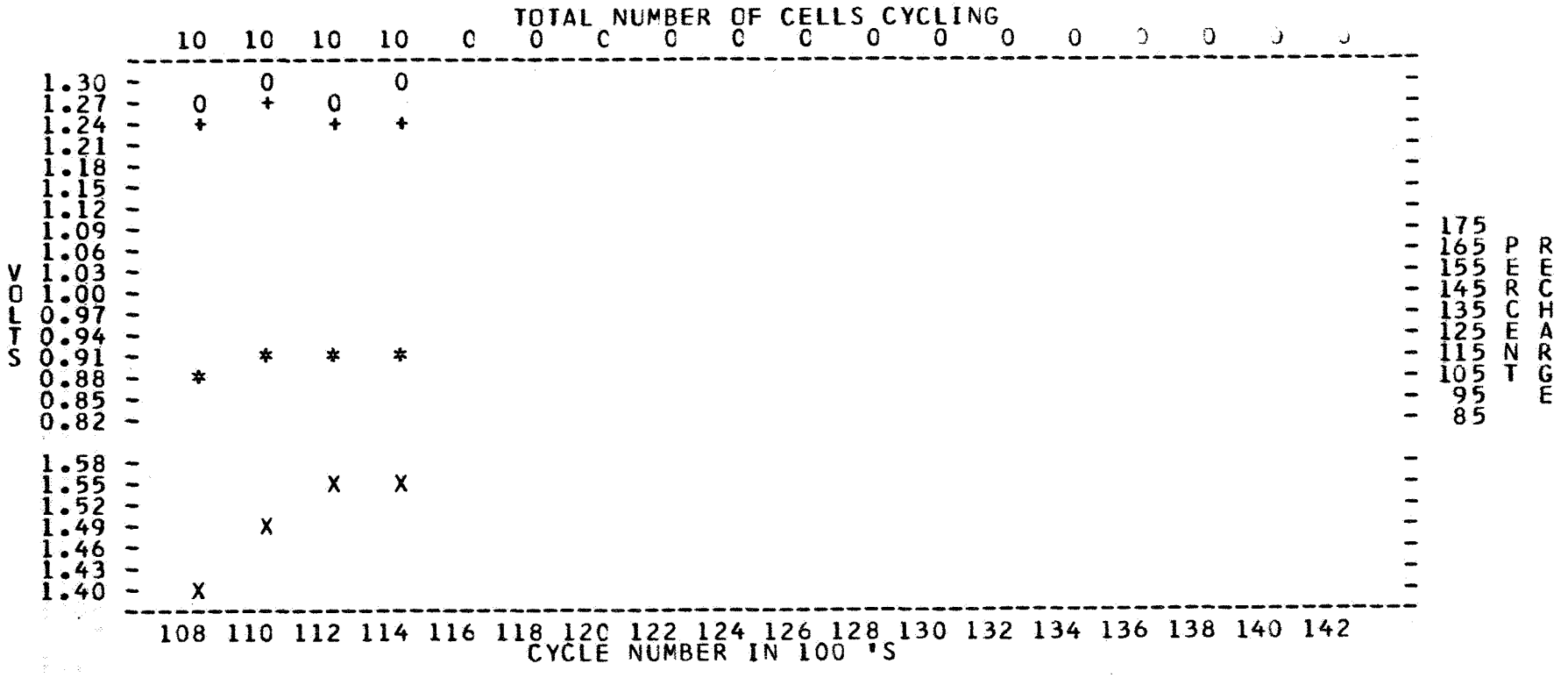
STATUS CELLS CYCLING 7
CYCLES COMPLETED 22525

CAPACITY CHECK CYCLES
1435, 2648, 3921, 5351, 6782
8739, 9978, 11691, 13077, 14382
15591, 17234, 18643, 19903, 21345
0, 0, 0, 0, 0

PACK DISCONTINUED BY REQUEST OF GODDARD SPACE FLIGHT CENTER.

FIGURE 9(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



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 11427

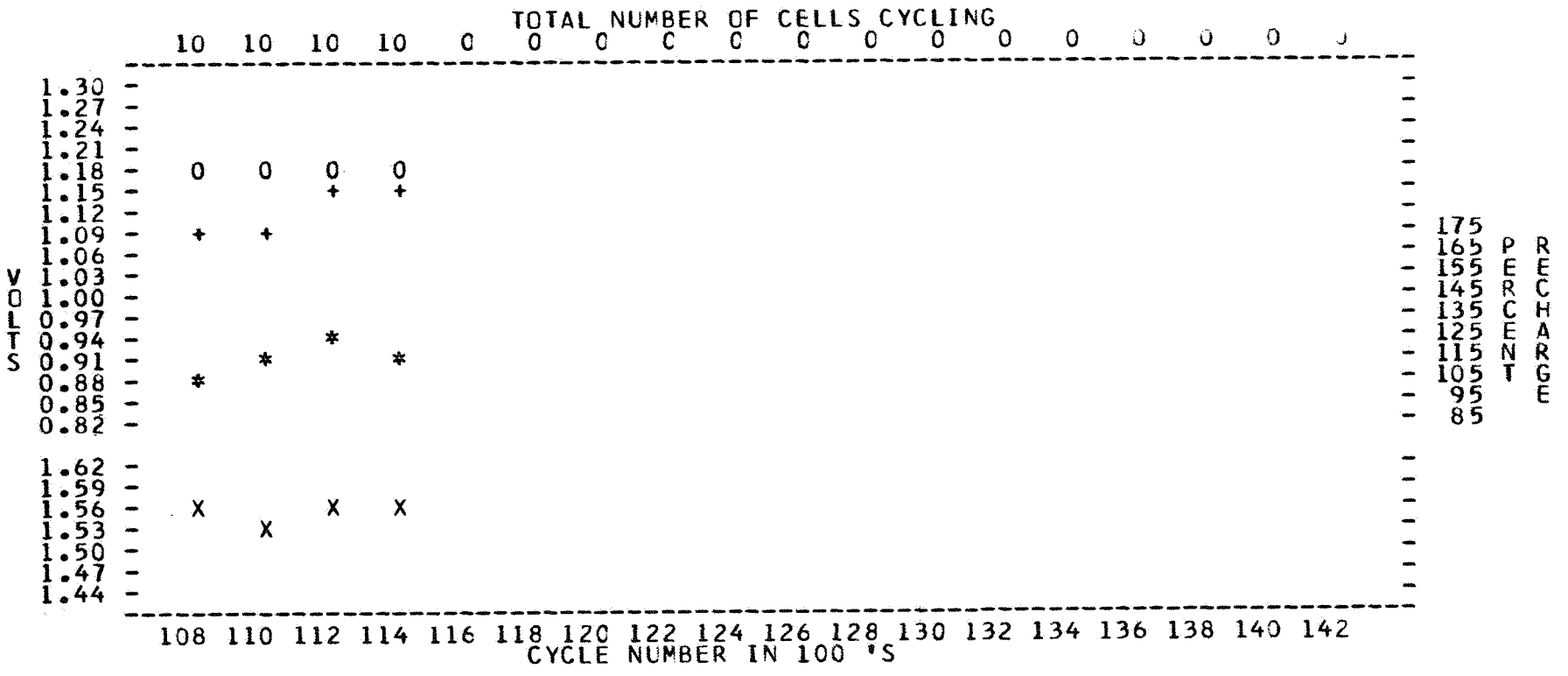
CAPACITY CHECK CYCLES
702, 1332, 2068, 2767, 3423
4272, 4854, 5719, 6496, 7234
8168, 8913, 9673,10226,10931
0, 0, 0, 0, 0

PACK DISCONTINUED BY REQUEST OF GODDARD SPACE FLIGHT CENTER.

FIGURE 9(C)

GE/C 69-244

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 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.

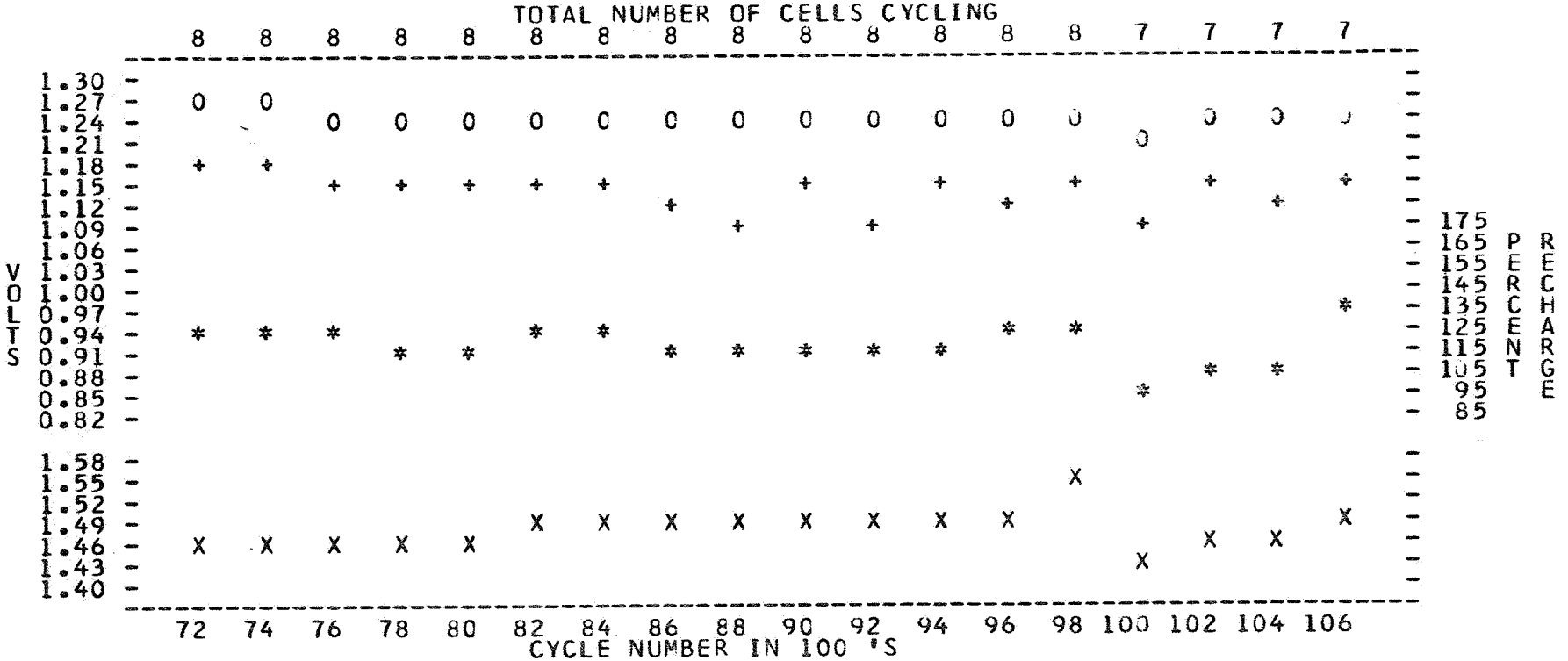
STATUS CELLS CYCLING 10
CYCLES COMPLETED 11331

CAPACITY CHECK CYCLES
701, 1310, 1984, 2681, 3433
4242, 4876, 5693, 6378, 7100
7886, 8721, 9465, 10074, 10766
0, 0, 0, 0, 0

PACK DISCONTINUED BY REQUEST OF GODDARD SPACE FLIGHT CENTER.

FIGURE 9(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
02	3134
03	5272
01	9971

PACK NUMBER 005A
TYPE OF CELLS SONOTONE 5.00 AH
TEST TEMPERATURE 25 DEGREES C.
ORBIT PERIOD 03.0 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 0.62 AMP.

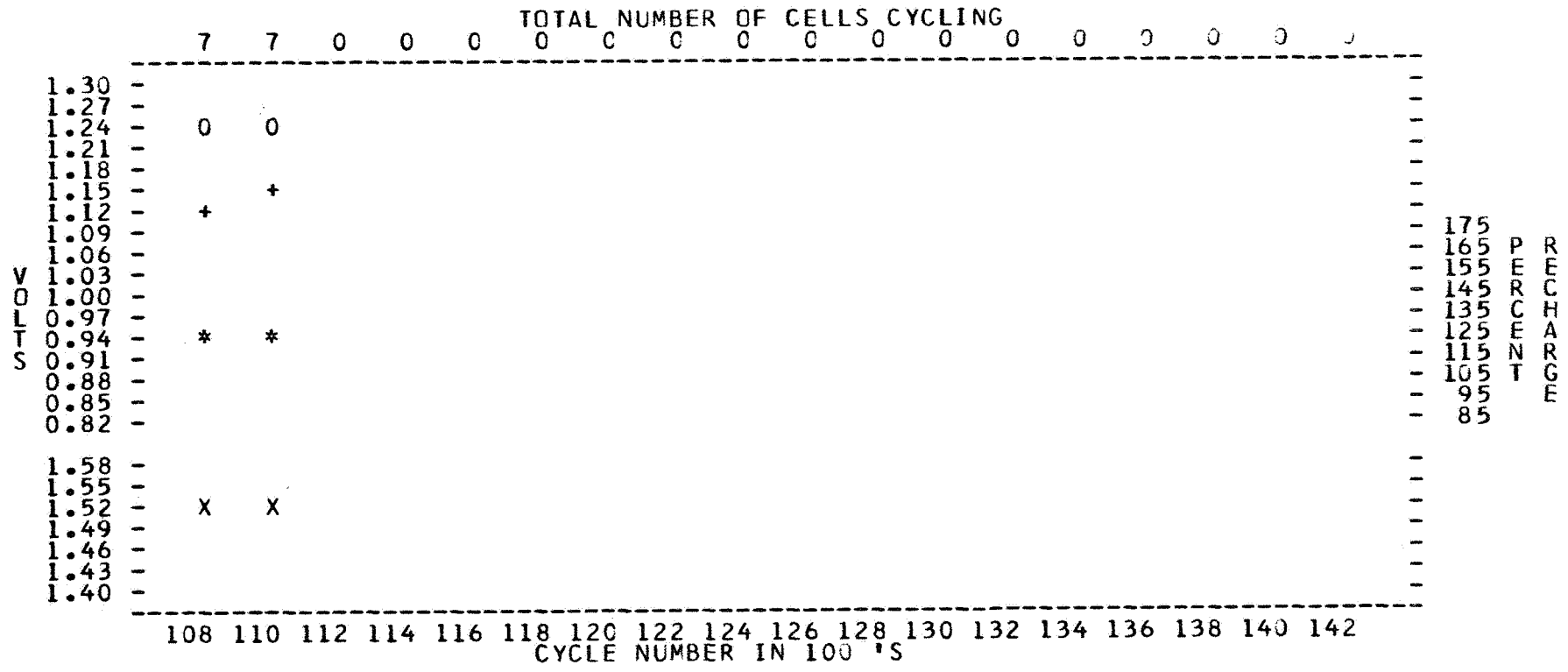
STATUS CELLS CYCLING 7
CYCLES COMPLETED 11092

CAPACITY CHECK CYCLES
702, 1368, 2125, 2823, 3437
4220, 4794, 5562, 6366, 7065
8023, 9583,10027,10731,

PACK DISCONTINUED BY REQUEST OF GODDARD SPACE FLIGHT CENTER.

FIGURE 9(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



POS. NO.	CYCLE FAILED
02	3134
03	5272
01	9971

PACK NUMBER 005A
TYPE OF CELLS SONOTONE 5.00 AH
TEST TEMPERATURE 25 DEGREES C.
ORBIT PERIOD 03.0 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 0.62 AMP.

STATUS CELLS CYCLING 7
CYCLES COMPLETED 11092

CAPACITY CHECK CYCLES
702, 1368, 2125, 2823, 3437
4220, 4794, 5562, 6366, 7065
8023, 9583,10027,10731,

PACK DISCONTINUED BY REQUEST OF GODDARD SPACE FLIGHT CENTER.

FIGURE 9(E) (CONTD)

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 were of necessity later changed to 40° C ambient. 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	GE 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 during 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 0° C the thermocouples are exposed to the rapidly moving air in the temperature chamber, which may account for the fact that the differences which had been observed at 25° C are less apparent. Thermocouple temperatures averaged 1° to 2° C above ambient, with the maximum temperature rise (8° to 9° C) being shown by the Gould 20 ah packs cycling at 1.5 hours. A comparison of the three temperature checks revealed that the temperature range had not changed.

3. 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° to 10° C above ambient. Generally, for each type, the packs at the 40 percent depth of discharge show temperatures 3° 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.

4. At 40° C the thermocouples are exposed to the rapidly moving air in the temperature chamber, which may account for the fact that the differences which had been observed at 25° C are less apparent. The majority of the packs showed almost no rise in the 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 4.3° to 12.3° 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 ah 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 Max.	Discharge Min.	Charge Max.	Charge 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 Max.	Discharge Min.	Charge Max.	Charge 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) End-of-charge Voltage: 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. Since January 1967 failure analyses have been performed within 1 week after the time of failure.

(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 320 failures; 53 were at 0° C, 128 at 25° C and 139 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 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	--	2	--	--	3	3	2	3	3	3	3	3
Gould 3.5 ah	2	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	--	1	6	6	3	6	6	6	6	6
TOTALS	16	21	6	10	34	35	24	35	33	38	34	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 25 failures, of which two were at 0° C, 11 were at 25° C and 12 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 63 cell failures, of which eight 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. The number of weak welds inside of the cells analyzed varied with temperature as indicated by 14 weak welds out of 29 failed cells at 40° C; 11 weak welds out of 26 failed cells at 25° C; and 1 weak weld out of 8 failed cells 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 51 cell failures, of which six were at 0° C, 21 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:
- X - Present
- 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 15 DECEMBER 1968

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)	+	+				X	
15%	63A	4	169	20126	1258	H	1.4	T	X				(b)		X	
					0° C; 3-hour orbit											
25%	68A	9	714	7054	882	L			X						X	
15%	67A	3	498	9980	1248	L		T	X				(b)		X	
					25° C; 1.5-hour orbit											
40%	16A	7	427	3985	249	N							(b)			
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			(P)							
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			(P)	+					X	
25%	15A	4	485	10382	649	L			(P)	+					X	
25%	15A	9	447	10382	649	L			(P)	+					X	
					25° C; 3-hour orbit											
40%	20A	5	421	3704	463	L			X	+					X	
40%	20A	2	433	4485	561	L			(P)	+			X		X	
40%	20A	6	711	4485	561	L		T	(P)	+					X	
40%	20A	3	710	4889	611	S		T	(P)	+					X	
40%	20A	4	415	5410	676	N		T	X	+					(X)	
40%	20A	9	721	5410	676	L			X	+					(X)	
25%	19A	1	551	8572	1072	N		T	X				(b)		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 15 DECEMBER 1968

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	0							X			
15%	43A	6	412	1911	239	0							b			
15%	43A	9	426	2298	287	0			P				b	X	X	
15%	43A	7	436	2515	314	0							b		X	3
15%	43A	10	435	2656	332	0			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 15 DECEMBER 1968

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										
25%	124A	3	417	13218	826	H	T	B	(P)		X		1
25%	124A	5	410	25786	1612			B,G	X		(X)		
			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		
25%	83A	3	447	12316	1540			B,G	X		(X)		
25%	83A	4	444	12822	1603			G	X		(X)		

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

TABLE Vb (Contd)

G.E. 12 ah CELLS. DATA ON CELL FAILURES THROUGH 15 DECEMBER 1968

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
				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)		
15%	86A	4	403	10661	1333	L		B,G	X		(X)		

TABLE Vc

GOULD 3.5 ah CELLS. DATA ON CELL FAILURES THORUGH 15 DECEMBER 1968

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			Ⓧ					Ⓒ	
15%	51A	4	113	17373	1086	L		T			Ⓧ					X	
0° C; 3-hour orbit (No Failures)																	

TABLE Vc (Contd)

GOULD 3.5 ah CELLS. DATA ON CELL FAILURES THROUGH 15 DECEMBER 1968

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	860	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					T	+					
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			T					X	
15%	27A	2	11	4485	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			T				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 15 DECEMBER 1968

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				(X)	
15%	84A	5	31	17040	1065	L	G	(W)	X				(X)	
				0° C; 3-hour orbit										
25%	94A	3	54	9110	1139	N	G		(X)			+	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 15 DECEMBER 1968

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	(W)						
40%	118A	4	R91	1963	123	L	G	(W)						
25%	104A	1	69	2672	167	L	G	(W)						
25%	104A	5	R36	2826	177	L	G	(W)				X		
40%	118A	5	92	2937	184	L	G					(X)		
25%	104A	3	5	2980	186	L	G						(X)	
				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		(P)	+			X	
25%	105A	3	23	5580	698	L	G		X				(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	(W)						4
25%	126A	4	R29	1509	94	L	G	(W)		+			X	
25%	126A	5	11	1569	98	L	G	(W)						
15%	112A	1	17	5005	313	L	G						(X)	
15%	112A	2	25	5005	313	L	G						(X)	
15%	112A	5	38	5213	326	L		(T)		+			(X)	
				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			(P)				X	
15%	108A	2	81	4003	500	S	G			+			X	5
15%	108A	3	82	4233	529	S	G	(T)	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 15 DECEMBER 1968

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	2397	2762	173	L						(X)				
25%	62A	10	1630	2995	187	H	6.8	T	B					+		1
25%	62A	4	1792	4066	254	L					(T)			+	X	
15%	61A	4	1825	4094	256	L			B			(X)	X	+		
15%	61A	10	2311	4285	268	L			B.			(X)	X	+		
15%	61A	6	2400	4413	276	L			B			(X)		+		
25%	62A	5	1806	4441	278	L			B			(X)		+		
25%	62A	7	2227	8590	537	L			B			(X)	X	+		
15%	61A	3	1636	9760	610	L	2.7		B	X		(X)	X	+	X	2
15%	61A	1	1616	10146	634	H	6.0	T		(X)			X		X	
					0° C; 3-hour orbit											
25%	66A	6	1794	1045	131	H	5.1		B	(X)						1
25%	66A	8	1843	1173	147	L				X		(X)				
25%	66A	5	1781	1237	155	H		T	B					(+)		1
25%	66A	3	1634	1417	177	N	2.3		B	X		(X)		+		
25%	66A	7	1823	2122	265	L	7.8	T	B	X			X	+		
25%	66A	4	1591	4414	552	N		T	B	(X)		(X)	P			
15%	65A	4	1284	5012	626	L		T	G	X	(T)		X	+		
15%	65A	6	2095	5706	713	L				(X)			P	+	X	
15%	65A	8	1808	6186	713	L				(X)			P	+	(X)	
15%	65A	5	2303	9431	1179	L				(X)			P	+	(X)	

* 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 15 DECEMBER 1968

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	L						⊗	X	+		
25%	17A	1	1757	2375	297	L						⊗				
25%	17A	2	1598	2449	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 15 DECEMBER 1968

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 15 DECEMBER 1968

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			(X)					
25%	115A	2	508	2203	138	H			B	(X)			+		
25%	115A	4	467	2291	143	H			B	(X)			(+)		
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			(B)	(X)					1
25%	116A	3	428	8274	1034	S			B			X		(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				(X)				
40%	87A	5	386	627	39	L	18.1		B		(X)				2
40%	87A	3	394	627	39	H	16.4	T	B		(X)				
40%	87A	4	454	627	39	L	21.6	T		(X)					
25%	73A	3	396	1776	111	N	23.7			X					3
25%	73A	1	387	6120	383	L	13.2		B			X	+	(X)	
25%	73A	4	465	7763	485	L		T		X	(X)	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					(X)				
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)		X			

* Additional Notes:
1. End of negative plates pushed into 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 15 DECEMBER 1968

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 15 DECEMBER 1968

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		(T)		P			
15%	49A	3	4370	10073	630	S					X	X		(X)		
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	(X)	
					0° C; 3-hour orbit											
25%	54A	3	4853	11331	1416	L		T			X		P		(X)	

TABLE Vg (Contd)

SONOTONE 5.0 ah CELLS. DATA ON CELL FAILURES THROUGH 15 DECEMBER 1968

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	(W)			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	(T)	X		P		X	
40%	2A	7	3631	5262	329	L				(W)	X		P	X	X	3
40%	2A	1	3611	6671	417	N		T	B		X			X	(X)	
25%	1A	6	4878	7782	486	N		T			X			(X)	(X)	
25%	1A	5	4868	11361	710	N		T			X			X	(X)	
25%	1A	3	4345	11745	734	N					X		P	X	(X)	
25%	1A	10	6802	11745	734	N		T			X		P	X	(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)		(X)	P			
25%	5A	2	4351	3771	471	H		T			X			(X)	X	
40%	6A	9	6875	3798	475	N			B		X			X	(X)	
40%	6A	7	6882	4608	576	N					(T)		P	(X)	X	
40%	6A	6	6880	5211	651	N					X		P	X	(X)	
25%	5A	3	4354	5272	659	N			G		X		P	X	X	
25%	5A	1	4234	9971	1246	L		T			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 15 DECEMBER 1968

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		(T)		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								(X)		
25%	26A	4	4240	3625	227	L			B		P				X	
15%	25A	5	4852	6348	397	H					P			(X)	(C)	
15%	25A	4	4364	7052	441	N		T	B		X			(X)	(X)	
15%	25A	1	4317	7758	485	L		T			X			X	(X)	
15%	25A	3	4350	9070	567	N		T		(W)					(X)	1
15%	25A	6	6850	9220	576	N		T				(X)				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		(X)	2
15%	29A	1	3626	1418	177	S					(S)		P			
25%	30A	4	3643	3068	384	L					(T)		P	(X)	(X)	
25%	30A	9	809	3068	384	L		T		(W)	(T)			(X)	X	
25%	30A	8	3658	3684	461	L	1.3	T			X			(X)	(X)	
25%	30A	1	3617	4141	518	S		T		(T)					(X)	
25%	30A	10	7230	4141	518	L		T			X				(X)	
15%	29A	8	4327	4340	543	N		T						(X)	(X)	
15%	29A	7	810	4835	604	L		T		(W)			P			
15%	29A	9	4340	4964	621	N			G		X		P	X	(X)	
15%	29A	5	6883	5581	698	N		T			X		P	X	(X)	
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 precycling capacity (as defined in Paragraph II.G.1.) as the percent of rated capacity of each of the four packs at 0°, 25° and 50° C are listed and compared in Table VI below. For example, the average precycling 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 precycling 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 precycling capacities, those at 40° C ranged from 39 to 65 percent, averaging 55 percent.

b. Comparing precycling 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 PRECYCLING CAPACITIES AS PERCENT OF: RATED CAPACITY				PRECYCLING 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

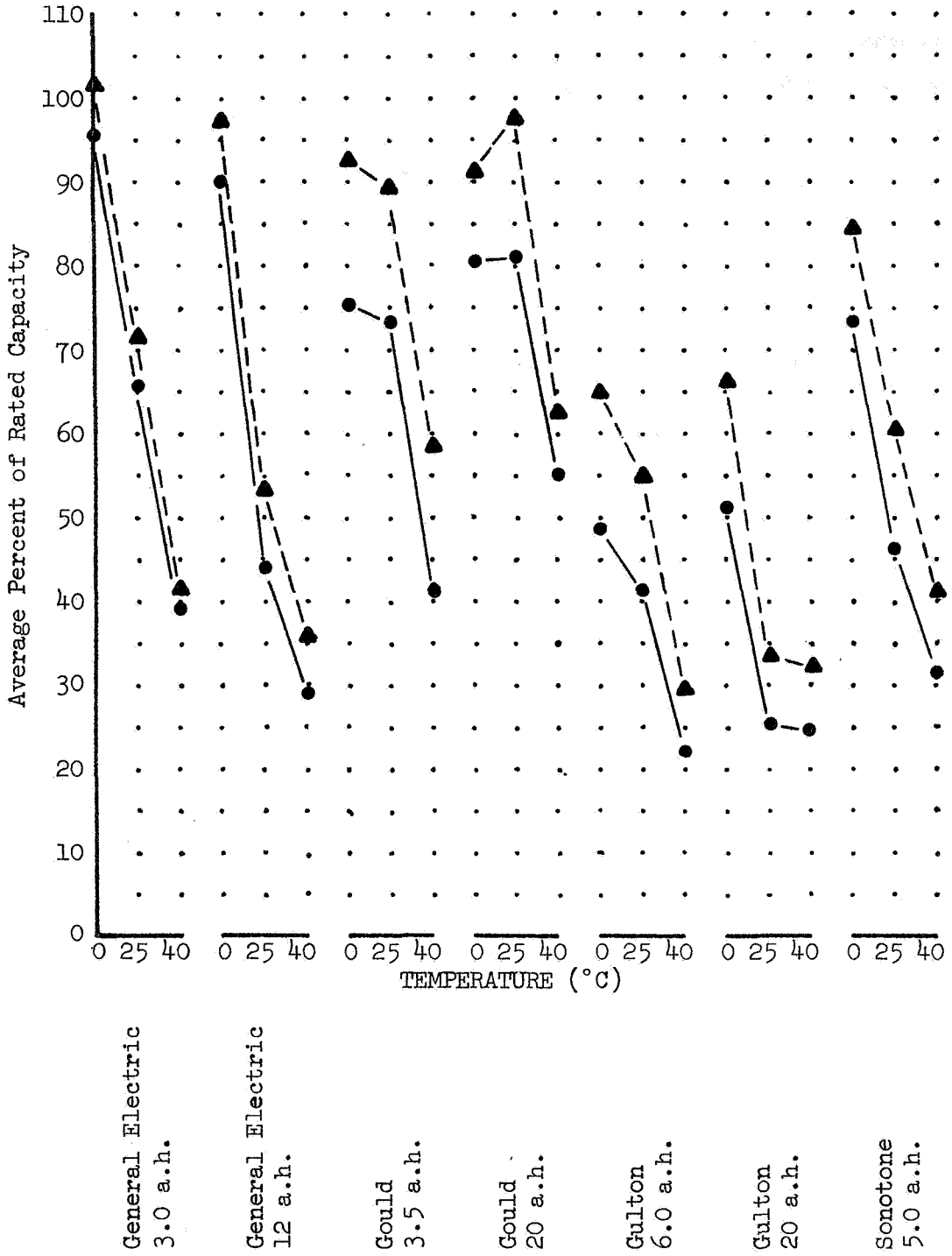
2. Obtainable Capacity Versus Temperature:

a. The capacity of the cells is affected by the temperature in which they are cycled. Figure 10 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 10 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. 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 10 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° 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 10

TABLE VIIa

G.E. 3.0 ah AMPERE-HOUR CAPACITIES ON PRECYCLING 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
Precycling 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
Precycling 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	0.86 F	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 F	1.33 F	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 F			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 F				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 F	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 F		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	3.08
	Disch #2								1.25 D	2.18 D	2.50 D	3.00 D	3.00 D

F - Failed
D - Discontinued

TABLE VIIb

G.E. 12 ah AMPERE-HOUR CAPACITIES ON PRECYCLING 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
Precycling 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
Precycling 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 F	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 F	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 F	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 F	4.40		5.70 F	4.90 F	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	8.10	12.1	9.00
	Disch #2				1.50 F				4.90	8.30	10.2	12.0	9.30

F - Failed
D - Discontinued

TABLE VIIb (Contd)

G.E. 12 ah AMPERE-HOUR CAPACITIES ON PRECYCLING 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
1408 Days	Disch #1								3.90	5.10	9.70	10.8	9.00
	Disch #2								4.60	8.00	10.2	11.8	8.80
1496 Days	Disch #1								3.00	4.80	7.10	10.1	8.30
	Disch #2								3.60	7.90	10.5	11.1	8.60
1584 Days	Disch #1								2.60	5.10	6.60	9.70	8.70
	Disch #2								4.70	7.50	11.1	11.3	8.80

TABLE VIIc

GOULD 3.5 ah AMPERE-HOUR CAPACITIES ON PRECYCLING 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
Precycling 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
Precycling 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	3.73	3.82	3.97	3.06
	Disch #2	2.86 F	1.49 F	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 F	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 F	2.16 F		3.03 F	2.25 F	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 F	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 F	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	2.83
	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 D	2.48	3.00 D
1408 Days	Disch #1											1.93	
	Disch #2											2.54 D	

F - Failed
D - Discontinued

TABLE VIId

GOULD 20 ah AMPERE-HOUR CAPACITIES ON PRECYCLING 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
Precycling 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
Precycling 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 F	8.17 F	12.2	9.83	23.3 F	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 F	14.0 F	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 F	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 F				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 F	15.8	19.8	16.7
704 Days	Disch #1								1.67		13.3	16.2	13.7
	Disch #2								14.3 F		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
1320 Days	Disch #1										12.0	14.0	10.8
	Disch #2										14.2 D	15.8 D	13.5 D

F - Failed
D - Discontinued

TABLE VIIe

GULTON 6.0 ah AMPERE-HOUR CAPACITIES ON PRECYCLING 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
Precycling 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
Precycling 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 F	2.15	1.70	2.05	3.45 F	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 F		3.16 F	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 F	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 F					2.30 F	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 F							3.30	3.45 F	2.15	5.15
616 Days	Disch #1									3.45		1.70	3.90
	Disch #2									3.95		1.75 F	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			2.40
	Disch #2									3.10			2.76 D
1320 Days	Disch #1									2.30			
	Disch #2									3.25 D			

F - Failed
D - Discontinued

TABLE VIIf

GULTON 20 ah AMPERE-HOUR CAPACITIES ON PRECYCLING 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
Precycling 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
Precycling Capacity at 40°		11.3	10.3	13.8	12.7								
88	Disch #1	4.50	4.50	6.00	5.67	F	F	5.67	4.00	4.83	20.1	12.5	18.8
Days	Disch #2	6.00	6.67	6.50	7.33			7.17	6.17	11.2 F	20.7	12.2	18.3
176	Disch #1	9.17	4.83	3.67	3.67			6.60	4.83		20.8	3.00	21.0
Days	Disch #2	10.3	6.67	4.83	5.33			9.50	7.17 F		21.8	5.67 F	25.2
264	Disch #1	7.33	6.17	3.93	3.17			5.33			17.7		20.2
Days	Disch #2	9.33 F	7.67	5.50	4.33			7.83			19.3		20.3
352	Disch #1		5.67	3.50	3.83			5.67			8.67		8.33
Days	Disch #2		6.83	4.67	5.33			8.67			17.5		19.5
440	Disch #1		5.83	2.67	3.00			5.50			14.2		15.5
Days	Disch #2		7.17	5.00	4.67			8.83 F			15.2		17.3
528	Disch #1		5.00	3.97	3.33						13.2		17.0
Days	Disch #2		5.50 F	5.17 F	5.00						15.8		16.7
616	Disch #1				3.33						13.2		13.5
Days	Disch #2				5.17						13.5		15.0
704	Disch #1				3.00						11.7		11.5
Days	Disch #2				6.16 F						13.2		14.8
792	Disch #1										11.0		9.83
Days	Disch #2										13.0		10.1
880	Disch #1										9.00		8.17
Days	Disch #2										12.0		10.0
968	Disch #1										5.17		7.16
Days	Disch #2										10.7		8.67
1056	Disch #1										9.17		7.00
Days	Disch #2										13.8		8.17
1144	Disch #1										10.2		6.00
Days	Disch #2										13.0		7.50
1232	Disch #1										8.67		5.67
Days	Disch #2										11.8		6.83
1320	Disch #1										10.2		4.67
Days	Disch #2										11.0 D		5.83 D

F - Failed
D - Discharged

TABLE VIIg

SONOTONE 5.0 ah AMPERE-HOUR CAPACITIES ON PRECYCLING 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
Precycling 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
Precycling 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 F	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 F	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 F	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 F	1.54 F		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 F	2.46 F	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								2.08	1.83	1.25	2.46	3.67
	Disch #2								2.79 D	2.96	1.92	3.38	4.13
1320 Days	Disch #1									1.75	1.21	2.71	3.75
	Disch #2									2.92 D	1.67 D	3.21 D	4.17 D

F - Failed
D - Discontinued

4. Capacity Versus Days of Cycling:

a. In general the capacity at 40° 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 11(A) through 11(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 precycling capacity. (For detailed explanation of precycling capacity and capacity checks see Paragraph II.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 precycling 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 precycling 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 precycling 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 precycling capacities, the average being 55.4 percent. At 40° C, 264-day capacities ranged from 48.9 to 117.5 percent of the 40° C precycling 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 precycling capacity and the other showed an increase in capacity with each capacity check.

c. Except for the Gould cells at 25° and 40° C, which retained a much higher percentage of their precycling 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 precycling capacity retained by the Gould cells after 264 days of cycling is due partly to the comparatively low precycling capacity.

TABLE VIII

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

Manufacturer and Type (a.h.)	AT 0° C				AT 25° C				AT 40° C			
	Number of Packs	Pre-cycling	After 264 Days of Cycling		Number of Packs	Pre-cycling	After 264 Days of Cycling		Number of Packs	Pre-cycling	After 264 Days of Cycling	
		Percent of Rated	Percent of Rated	Percent of Pre-cycling		Percent of Rated	Percent of Rated	Percent of Pre-cycling		Percent of Rated	Percent of Rated	Percent of Pre-cycling
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	48.9
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

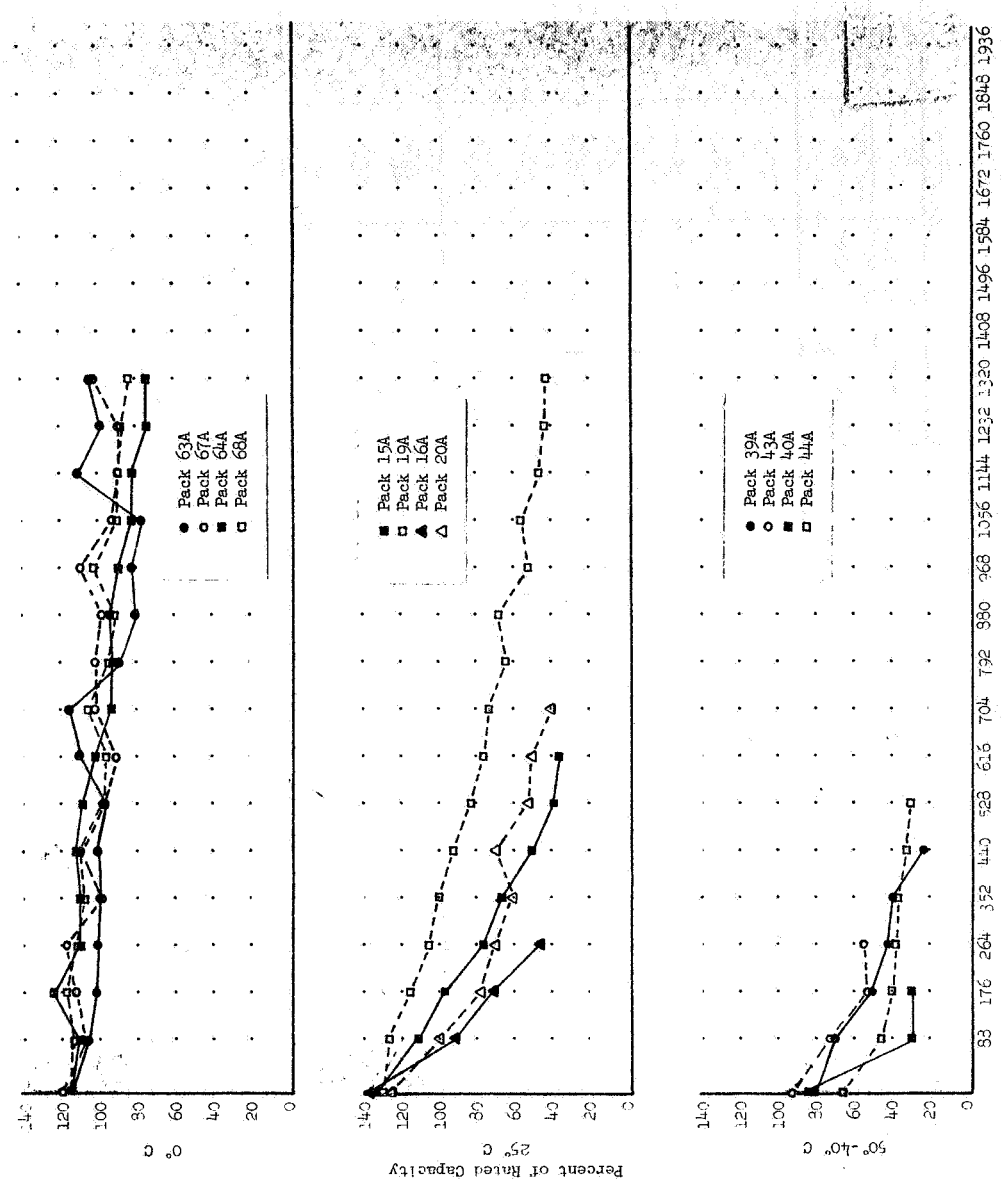

Pack 63A
Pack 67A
Pack 64A
Pack 68A
Pack 15A
Pack 19A
Pack 16A
Pack 20A
Pack 39A
Pack 43A
Pack 40A
Pack 44A
0° C
25° C
50°-40° C
Percent of Rated Capacity
Days of Cycling
88 176 264 352 440 528 616 704 792 880 968 1056 1144 1232 1320 1408 1496 1584 1672 1760 1848 1936
PRECYCLING AND CAPACITY CHECK CYCLES
(Measured ampere-hours expressed as percent of rated capacity)
1.5-hr. period
3.0-hr. period
Depth of Discharge
G.E. 3.0 ah

Figure 11(A)

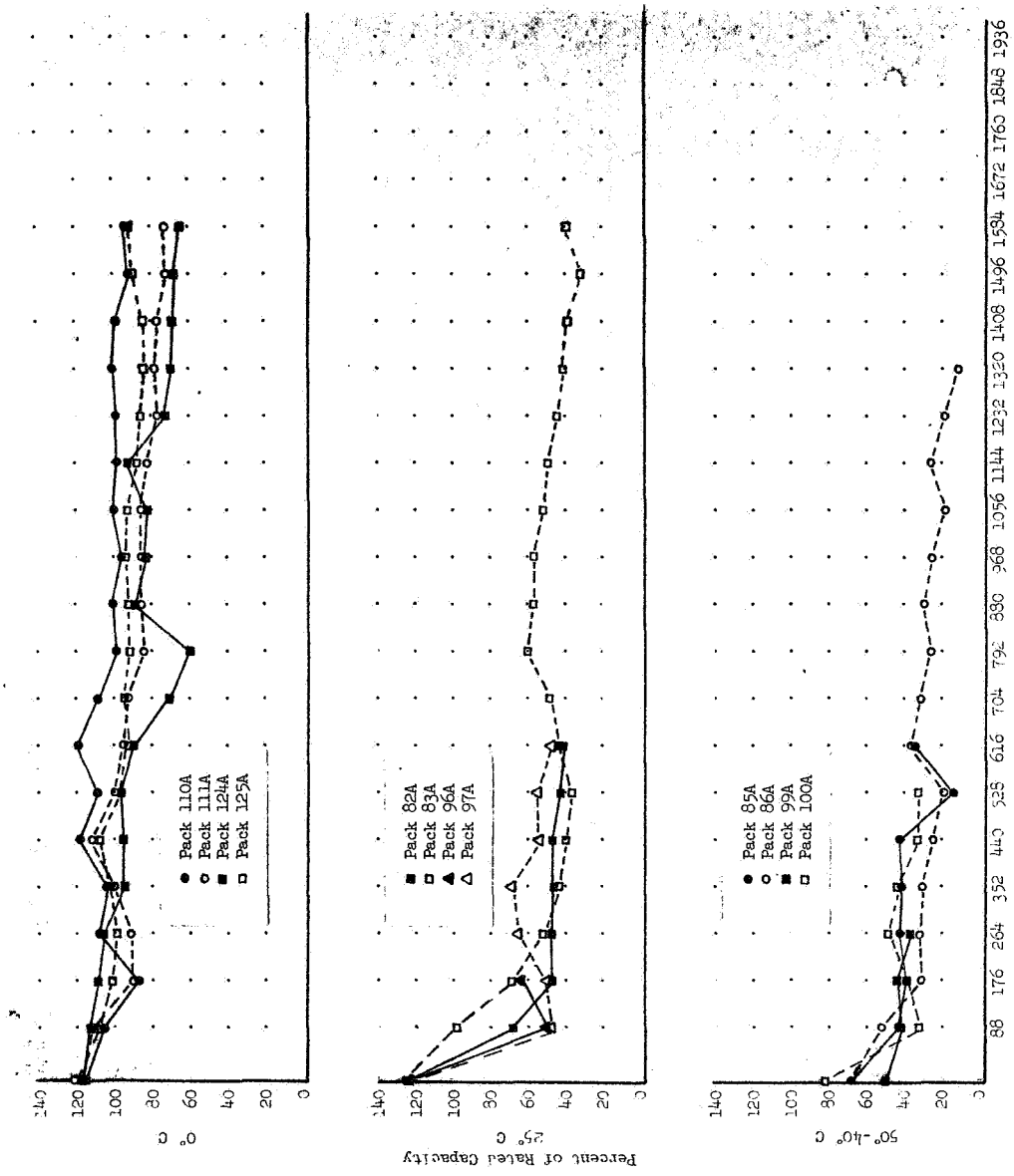

Percent of Rated Capacity
0° C
25° C
50°-40° C
Pack 110A
Pack 111A
Pack 124A
Pack 125A
Pack 82A
Pack 83A
Pack 96A
Pack 97A
Pack 85A
Pack 86A
Pack 99A
Pack 100A
88 176 264 352 440 528 616 704 792 880 968 1056 1144 1232 1320 1408 1496 1584 1672 1760 1848 1936
Days of Cycling
PRECYCLING AND CAPACITY CHECK CYCLES
(Measured ampere-hours expressed as percent of rated capacity)
1.5-hr. period
3.0-hr. period
Depth of Discharge
15%
25%
40%
G.E. 12 ah

Figure 11(B)

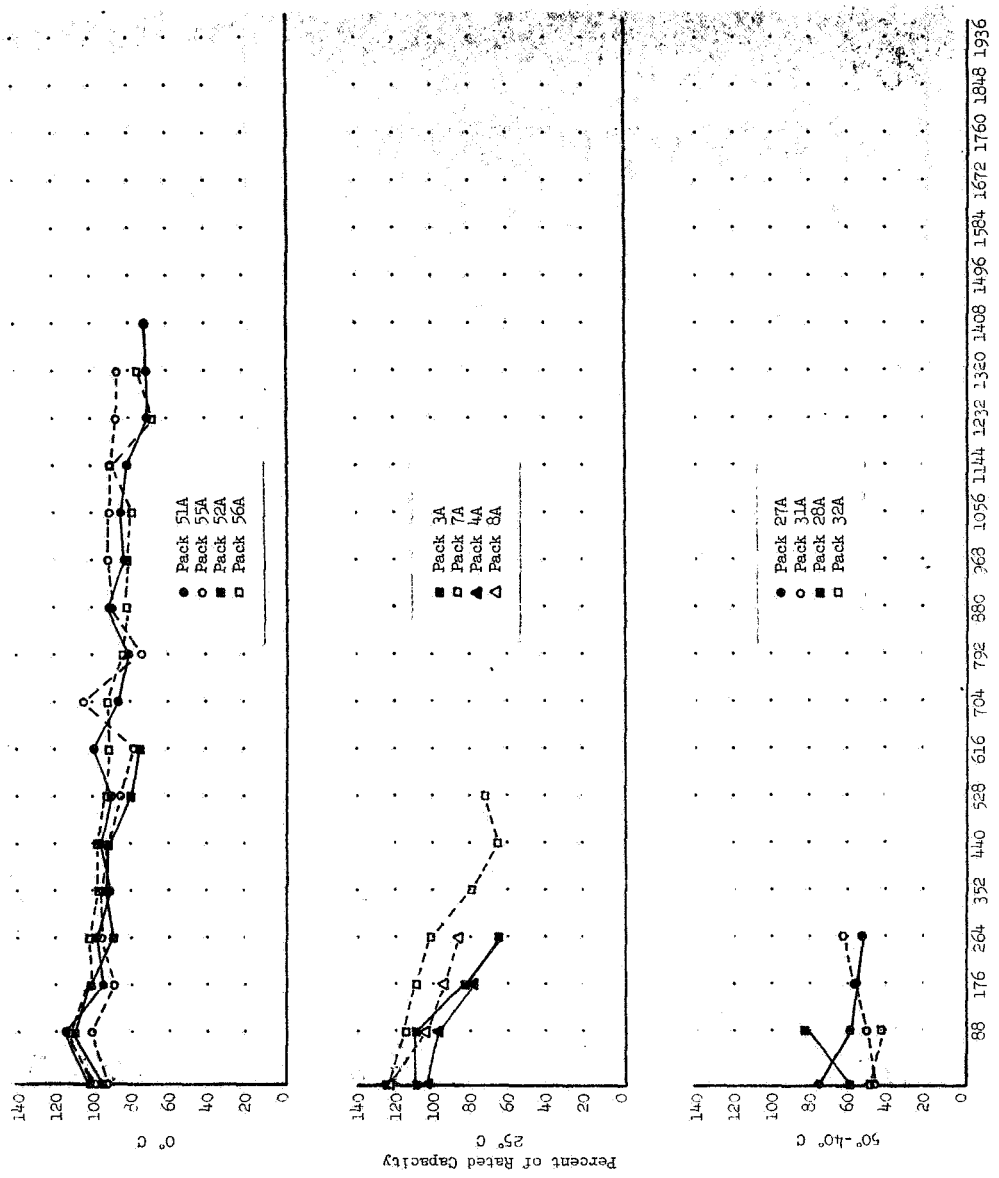

Percent of Rated Capacity
0° C
25° C
50°-40° C
Pack 51A
Pack 55A
Pack 52A
Pack 56A
Pack 3A
Pack 7A
Pack 4A
Pack 8A
Pack 27A
Pack 31A
Pack 28A
Pack 32A
0
20
40
60
80
100
120
140
88
176
264
352
440
528
616
704
792
880
968
1056
1144
1232
1320
1408
1496
1584
1672
1760
1848
1936
Days of Cycling
Gould 3.5 ah
PRECYCLING 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 11(C)

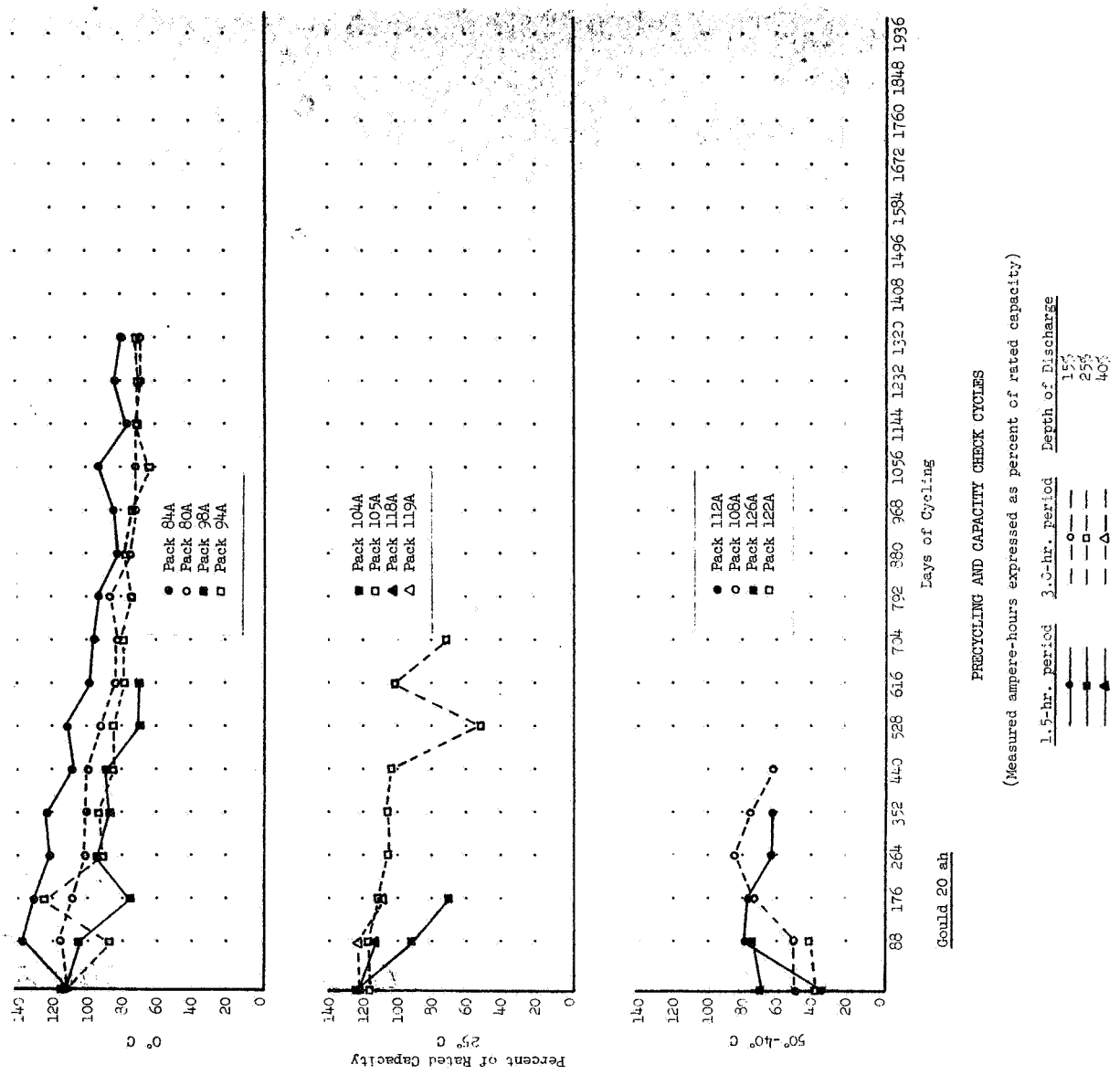

PRECYCLING AND CAPACITY CHECK CYCLES
(Measured ampere-hours expressed as percent of rated capacity)
1.5-hr. period
3.0-hr. period
Depth of Discharge
15%
25%
40%
Could 20 ah
Pack 84A
Pack 80A
Pack 98A
Pack 94A
Pack 104A
Pack 105A
Pack 118A
Pack 119A
Pack 112A
Pack 108A
Pack 126A
Pack 122A
0° C
25° C
50°-40° C
Percent of Rated Capacity
Days of Cycling
88 176 264 352 440 528 616 704 792 880 968 1056 1144 1232 1320 1408 1496 1584 1672 1760 1848 1936
0 20 40 60 80 100 120 140

Figure 11(D)

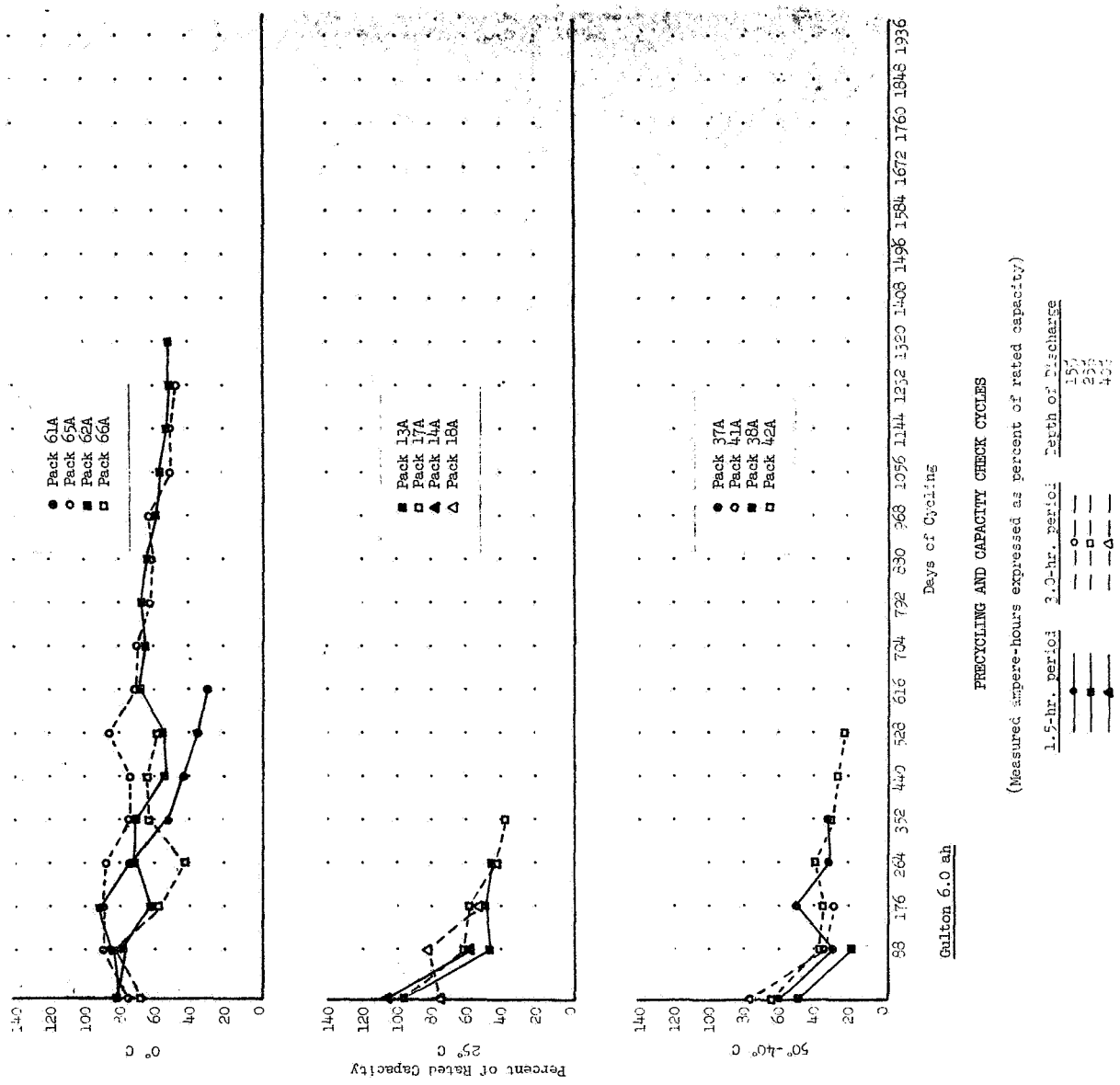

Pack 61A
Pack 65A
Pack 62A
Pack 66A
Pack 13A
Pack 17A
Pack 14A
Pack 18A
Pack 37A
Pack 41A
Pack 38A
Pack 42A
0° C
25° C
50°-40° C
Percent of Rated Capacity
Days of Cycling
PRECYCLING AND CAPACITY CHECK CYCLES
(Measured ampere-hours expressed as percent of rated capacity)
1.5-hr. period
3.0-hr. period
Depth of Discharge
Gulton 6.0 ah

Figure 11(E)

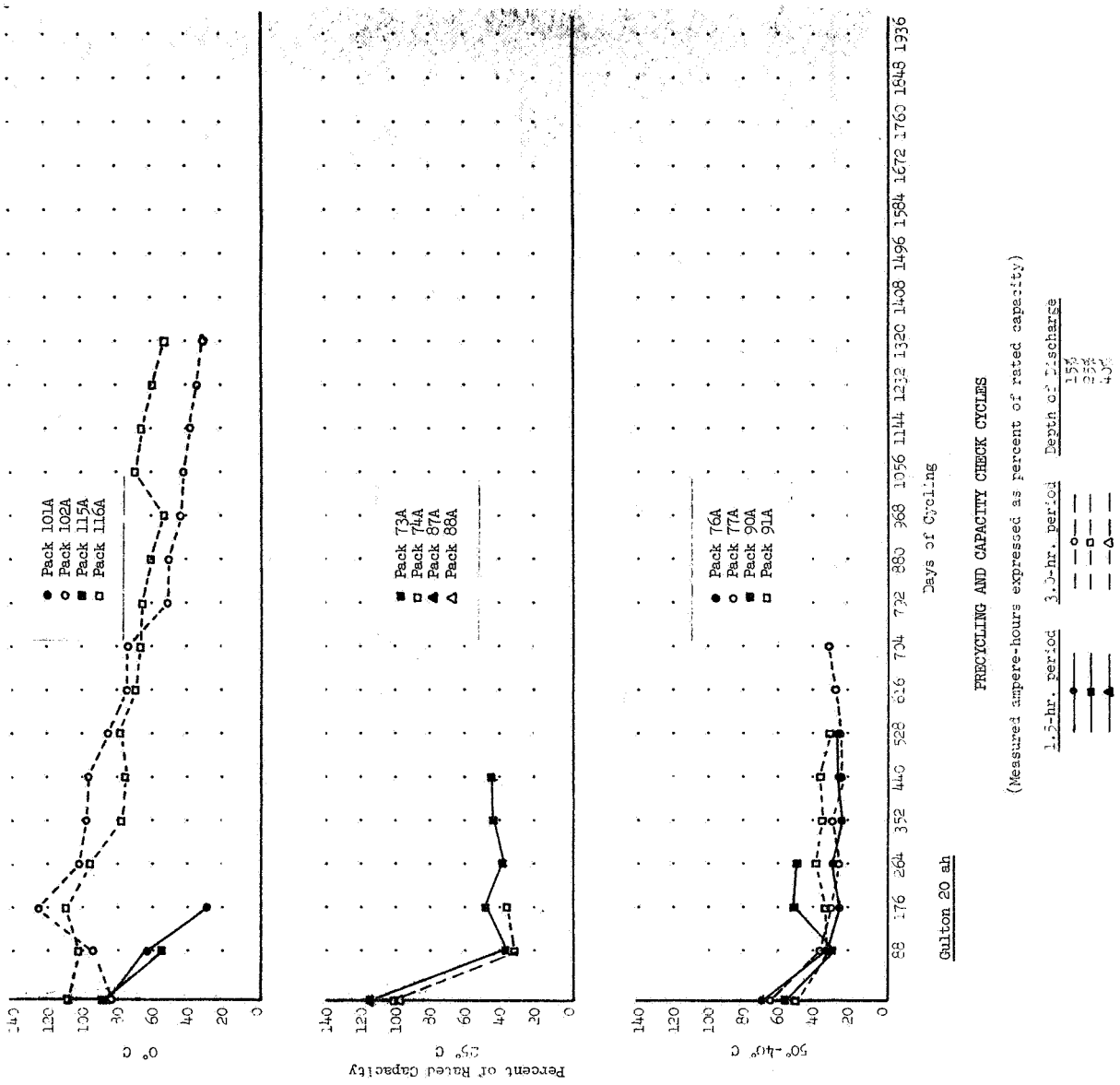

Pack 101A
Pack 102A
Pack 115A
Pack 116A
Pack 73A
Pack 74A
Pack 87A
Pack 88A
Pack 76A
Pack 77A
Pack 90A
Pack 91A
0° C
25° C
50°-40° C
Percent of Rated Capacity
Days of Cycling
88 176 264 352 440 528 616 704 792 880 968 1056 1144 1232 1320 1408 1496 1584 1672 1760 1848 1936
Gulton 20 ah
FREECYCLING AND 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 11(F)

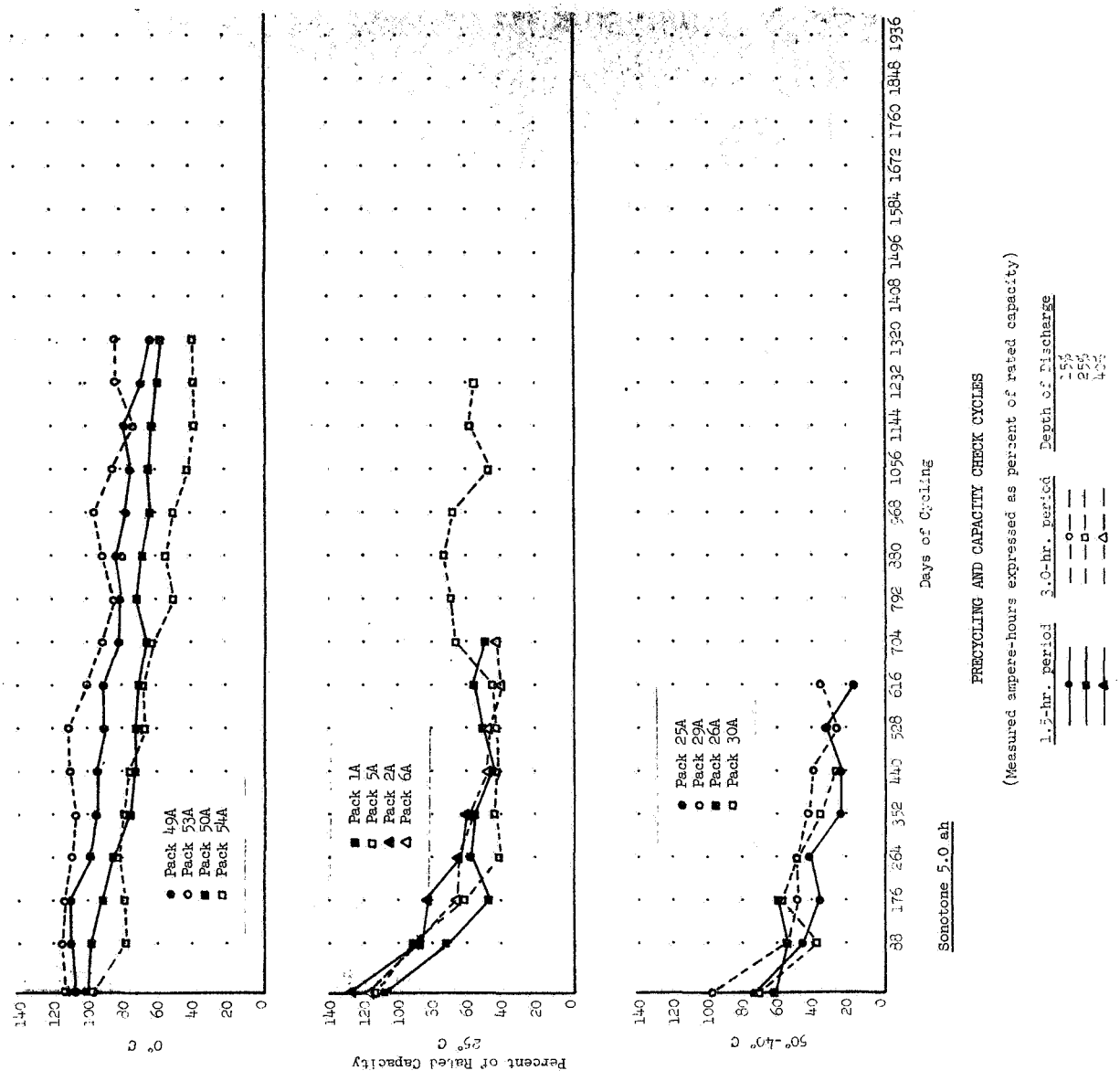

Sonotone 5.0 ah
PRECYCLING AND CAPACITY CHECK CYCLES
(Measured ampere-hours expressed as percent of rated capacity)
1.5-hr. period
3.0-hr. period
Depth of Discharge
Days of Cycling
Percent of Rated Capacity
0° C
25° C
50°-40° C
Pack 49A
Pack 53A
Pack 50A
Pack 54A
Pack 1A
Pack 5A
Pack 2A
Pack 6A
Pack 25A
Pack 29A
Pack 26A
Pack 30A

Figure 11(G)

IV. 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 to 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 12 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 45P 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.

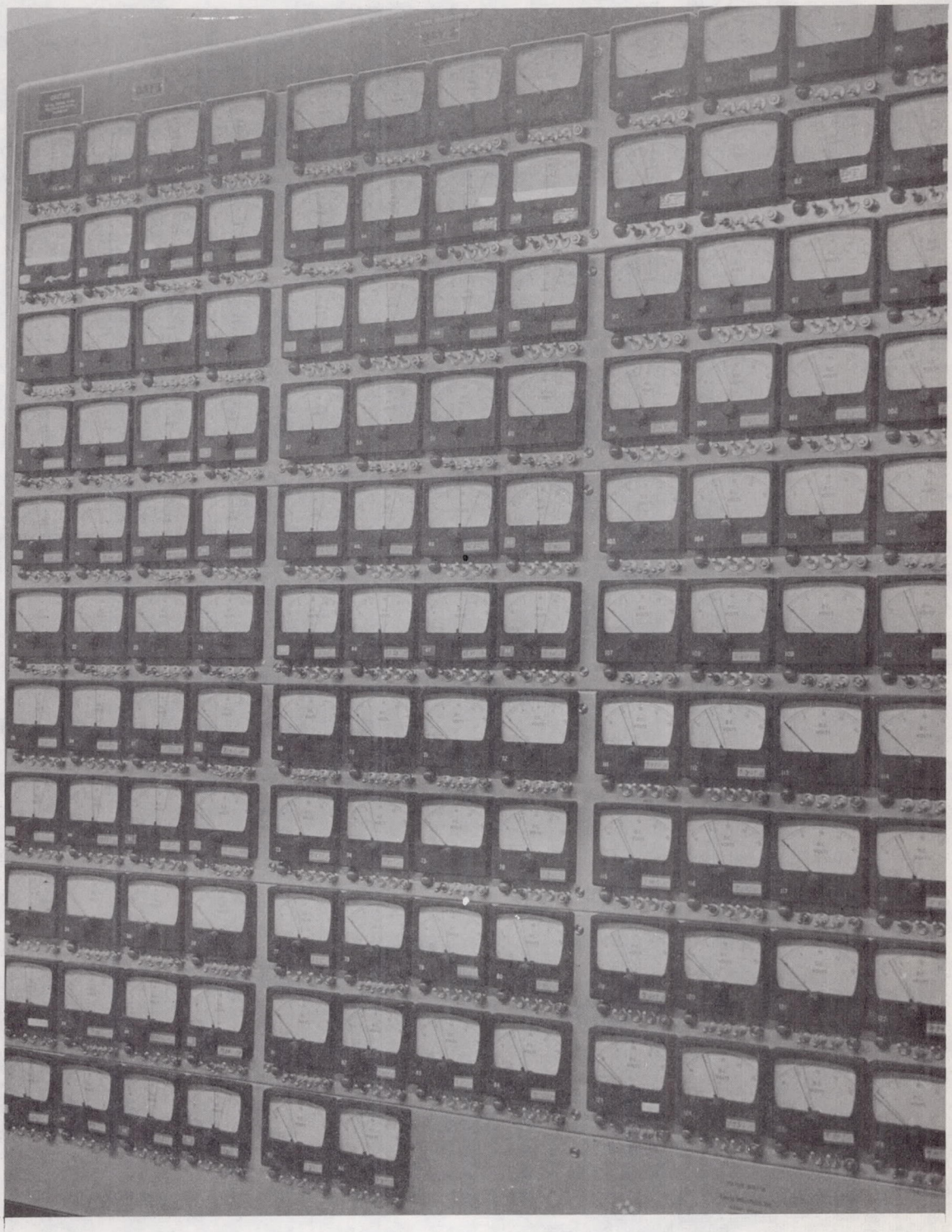
3. Photograph 4 shows the pack selector switch located on top of the data logging system.

G. Block Diagram of Entire Test Setup: Figure 13 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.

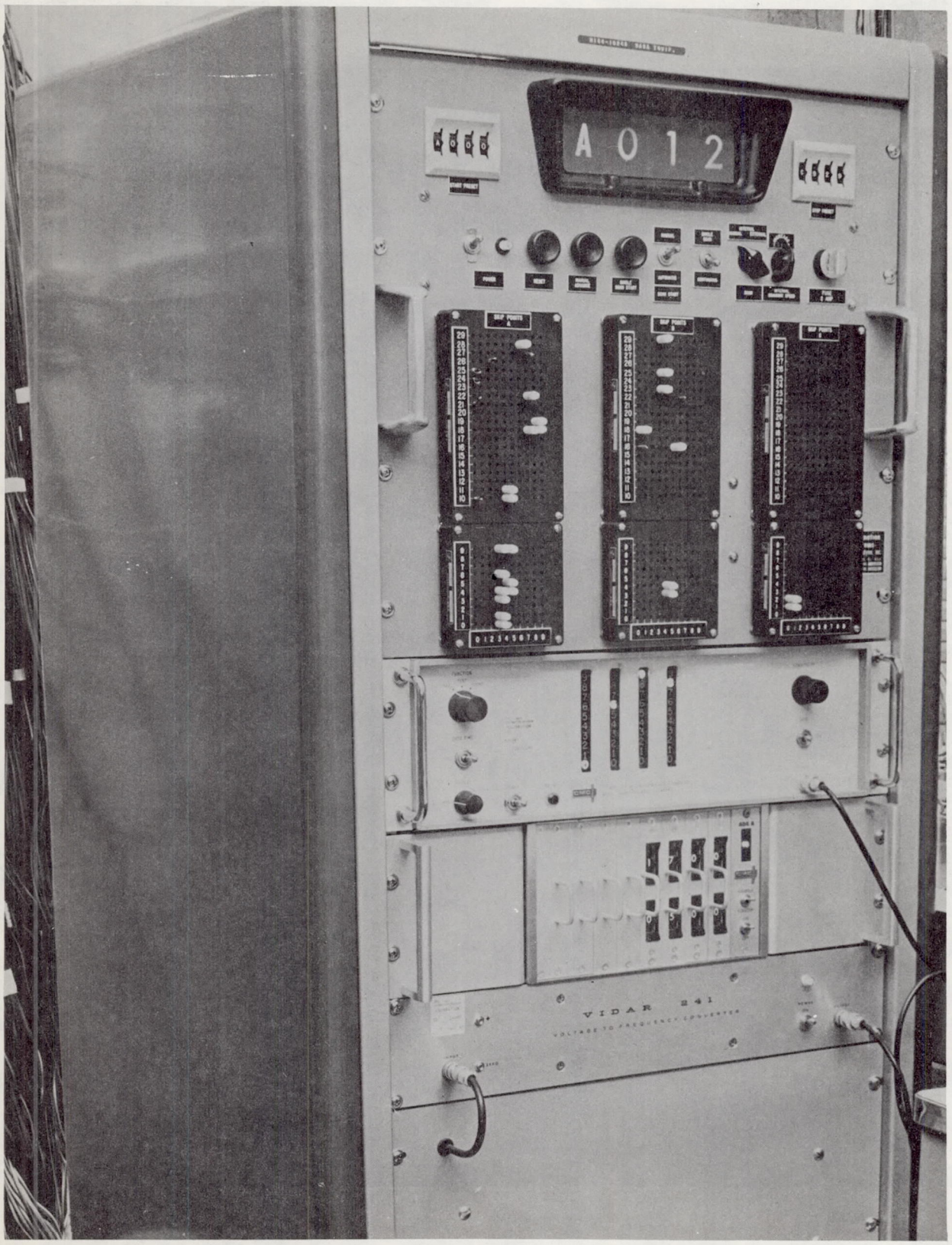
H. Photograph of Test Area: Photograph 7 shows the overall arrangement of the test equipment described in paragraphs IV.B. through IV.G.



Several Charge and Discharge Control Units
PHOTOGRAPH 2

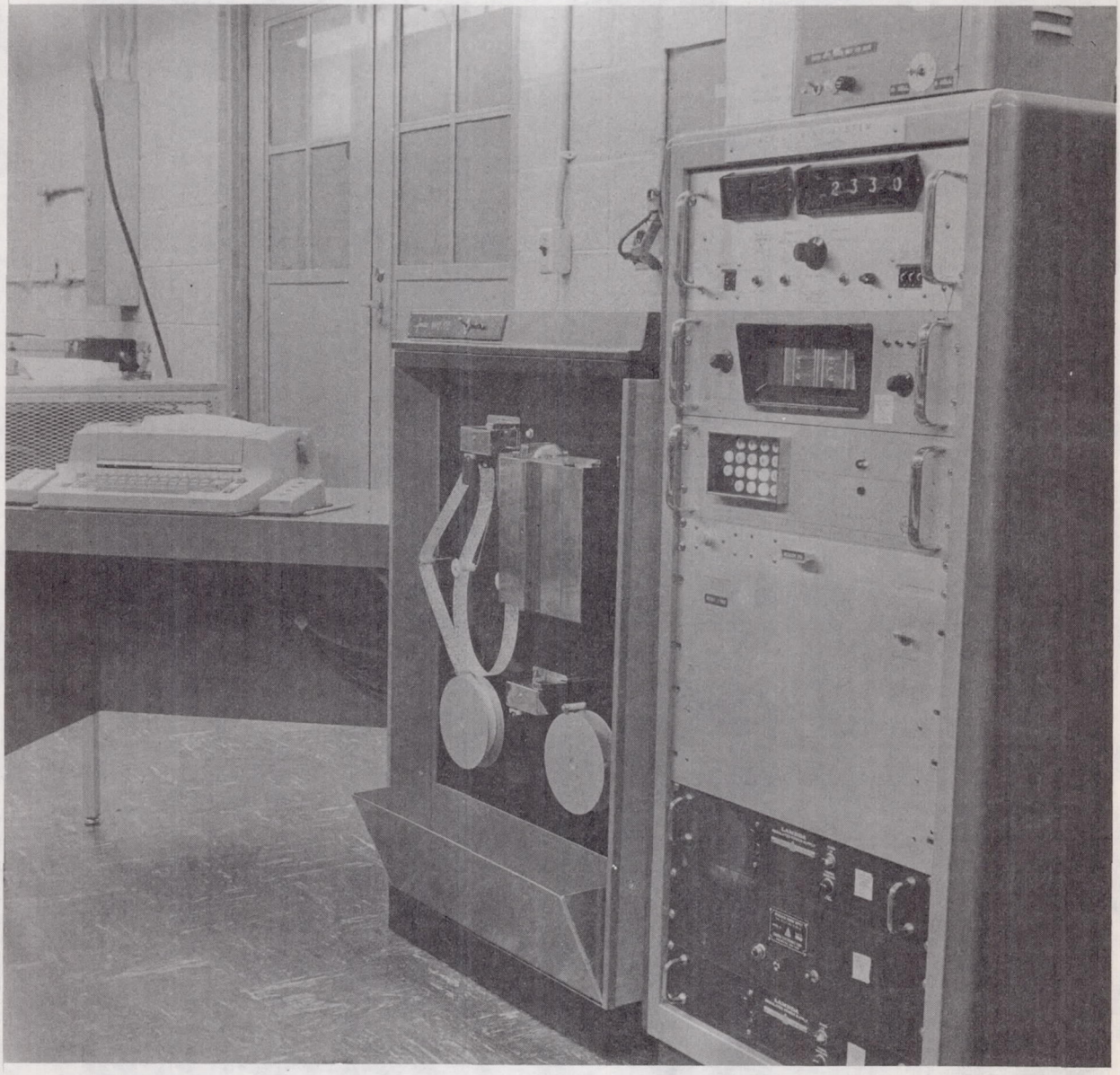


Pack Voltage Monitoring Panel
PHOTOGRAPH 3



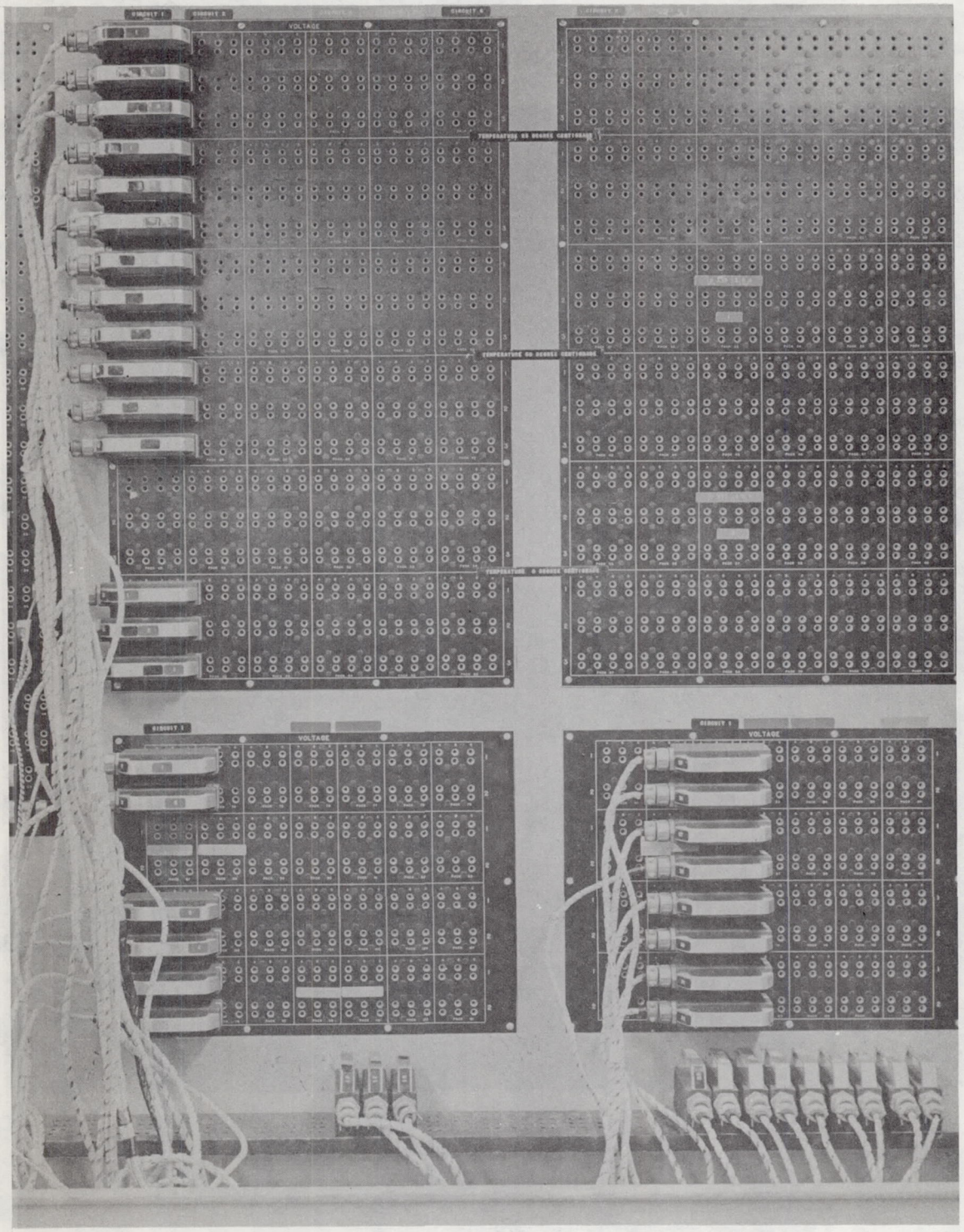
Individual Cell Voltage Scanning System

PHOTOGRAPH 4



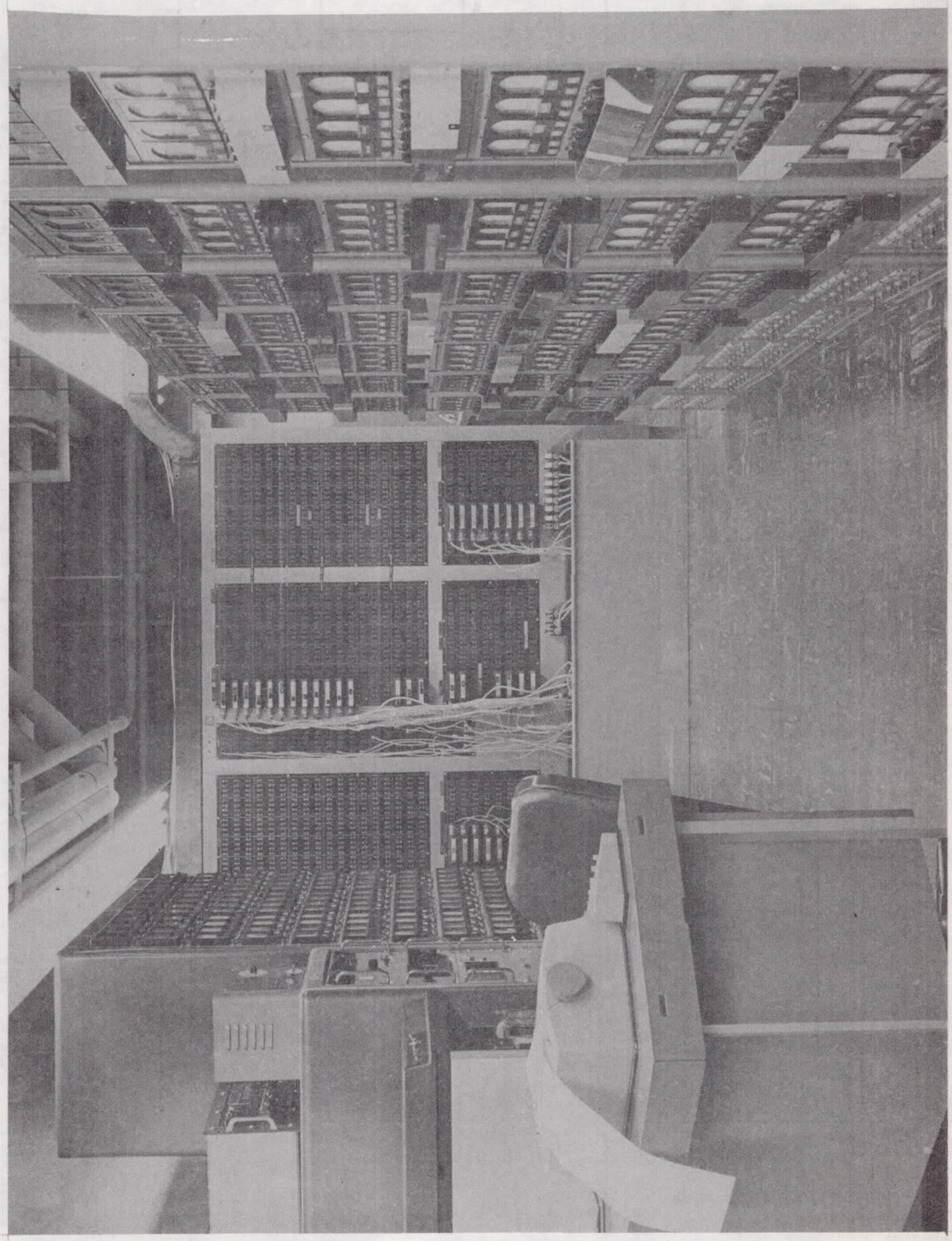
Data Logging System

PHOTOGRAPH 5

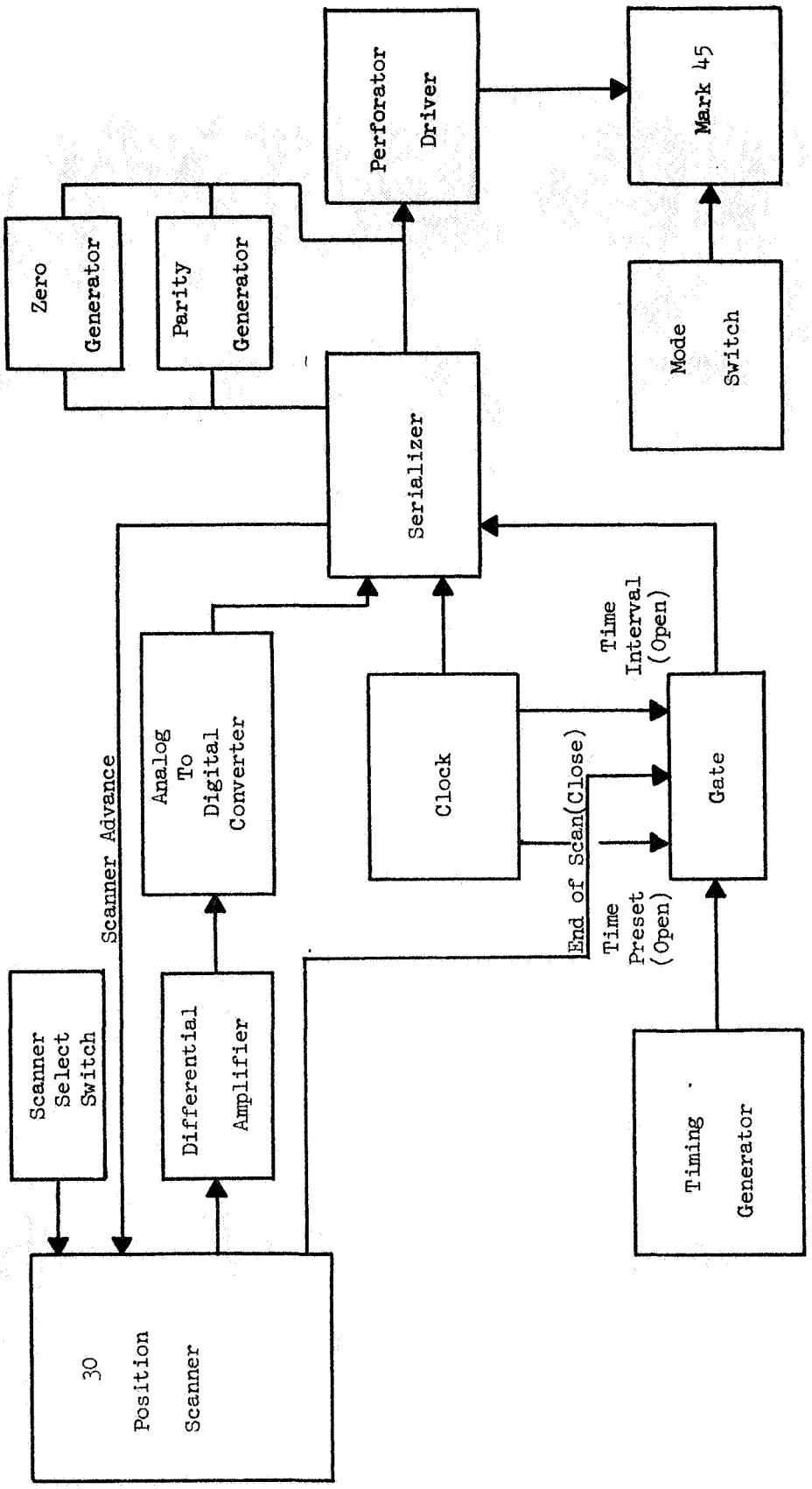


Portion of Central Wiring Panel

PHOTOGRAPH 6

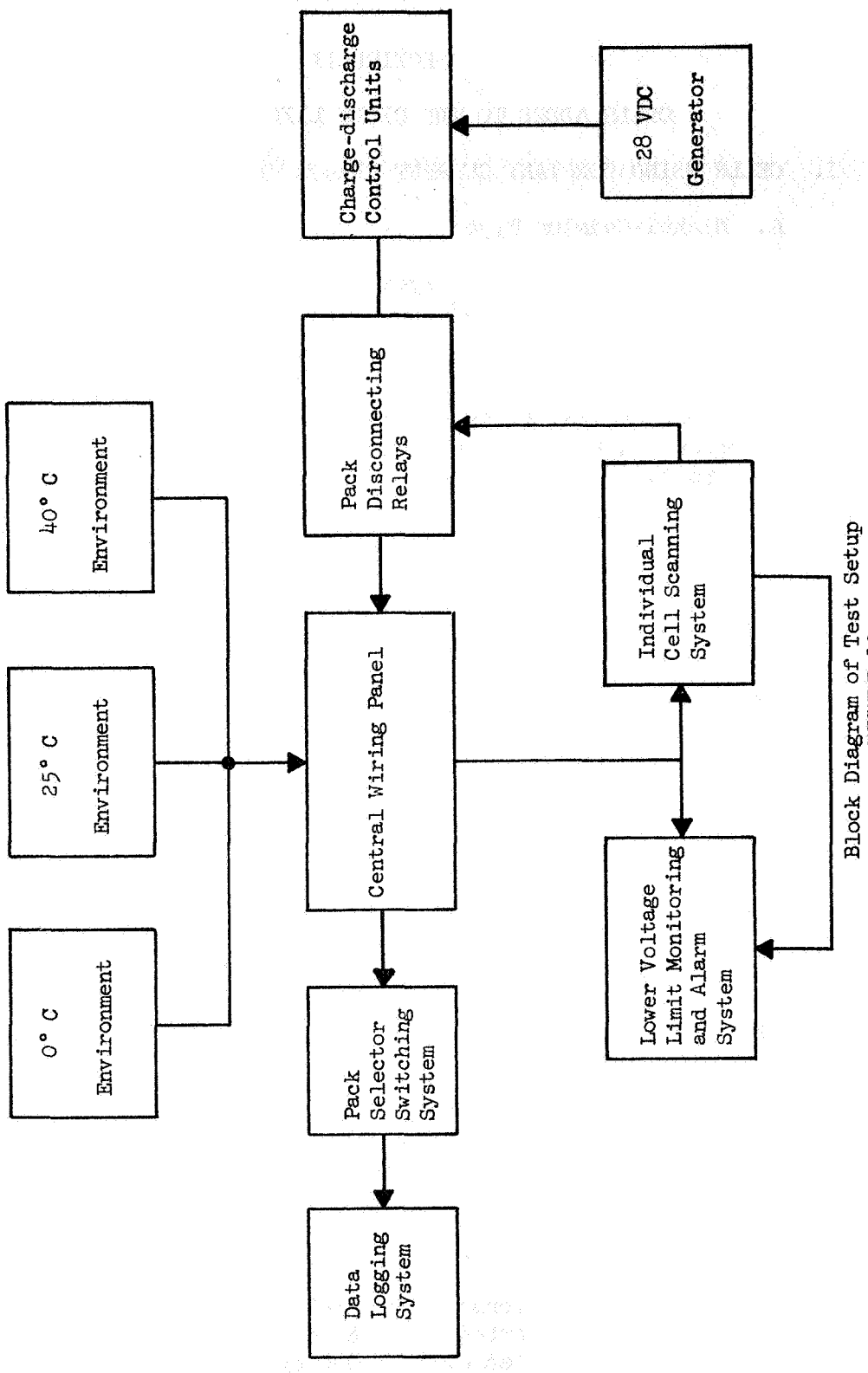


Test Area
PHOTOGRAPH 7



Block Diagram of Data Logging System

FIGURE 12



Block Diagram of Test Setup
FIGURE 13

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 14(A) through 14(G).) Cycling was started in December 1966. Packs 89C, 122C, 99C and 87C have completed over 11,000 cycles to date with no cell failures.

(a) Pack 73C: This pack failed on cycle 9978 with its third cell failure. The other two cell failures occurred on cycles 8940 and 9406. Failure of the three cells was due to migration of negative plate material and separator deterioration. The cells also had high internal pressure as evidenced by outgassing when opening the containers. Two of the three cells had leaks around the rubber seal as indicated by carbonate deposits.

(b) Pack 112C: This pack, still cycling, has completed 10,865 cycles to date, with two cell failures which occurred on cycles 9392 and 10,536. Failure of both cells was due to migration of negative plate material and separator deterioration. They both had high internal pressure as evidenced by outgassing when opening the containers. The end-of-discharge voltages of these cells cycling at 40° C were much lower than those cycling at the lower temperatures.

(c) Pack 75D: This pack, still cycling, has completed 9866 cycles to date with one cell failure at cycle 3925. Failure was due to migration of negative plate material and separator deterioration. This cell also had high internal pressure as evidenced by the bulged case.

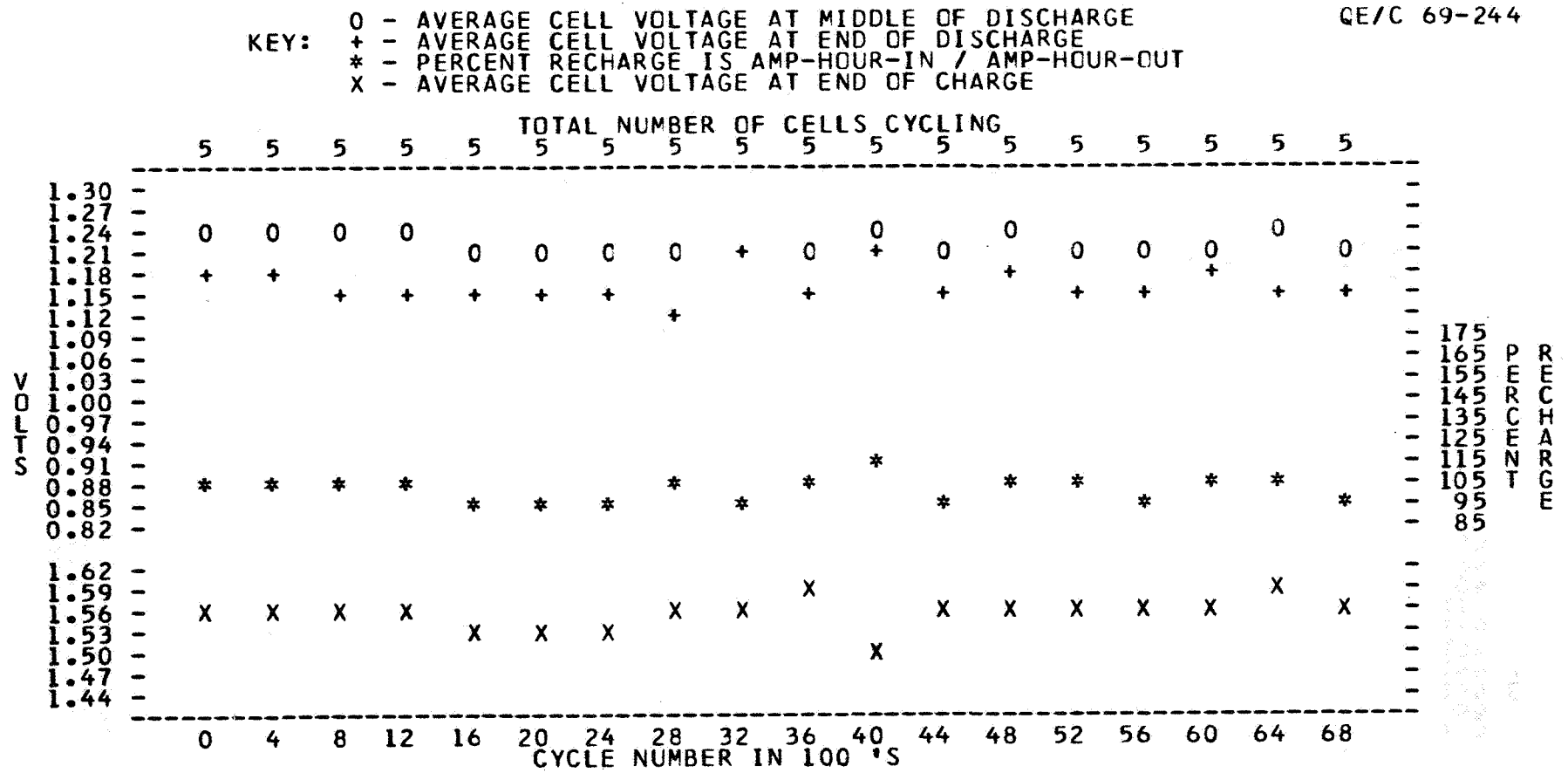
(d) The one 5-cell pack that was put on continuous charge has not shown any signs of high pressure or leakage.

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

PRECYCLING 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
Precycling 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
440 Days	Disch #1	1.02	1.75	2.51	3.12	2.01	1.49	0.96
	Disch #2	2.33	3.30	2.65	3.65	2.01	1.87	1.05
528 Days	Disch #1	1.81	1.98	2.45	2.33	1.52	1.69	0.99
	Disch #2	3.79	3.94	2.57	3.35	3.21	1.98	1.25
616 Days	Disch #1	1.31	1.98	2.33	2.42	1.14	1.31	0.82
	Disch #2	1.72	2.77	2.45	3.12	1.17	1.60 F	1.08
704 Days	Disch #1	0.99	1.90	2.19	2.27	0.96		0.90
	Disch #2	1.49	2.60	2.33	2.95	1.17		1.08

F - Failed



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.

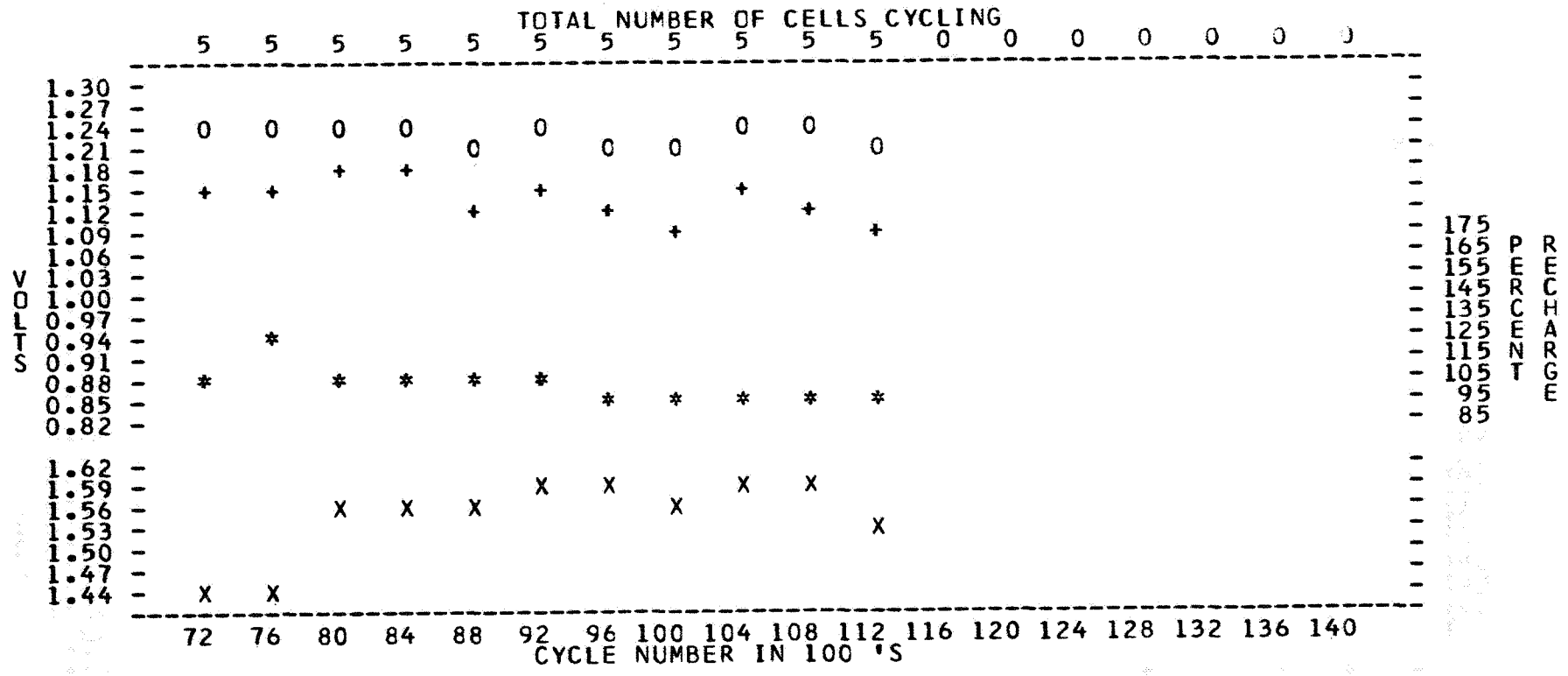
STATUS CELLS CYCLING 5
CYCLES COMPLETED 11089

CAPACITY CHECK CYCLES
1300, 2907, 4088, 5419, 6745
8233, 9638,

FIGURE 14(A)

QE/C 69-244

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 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.

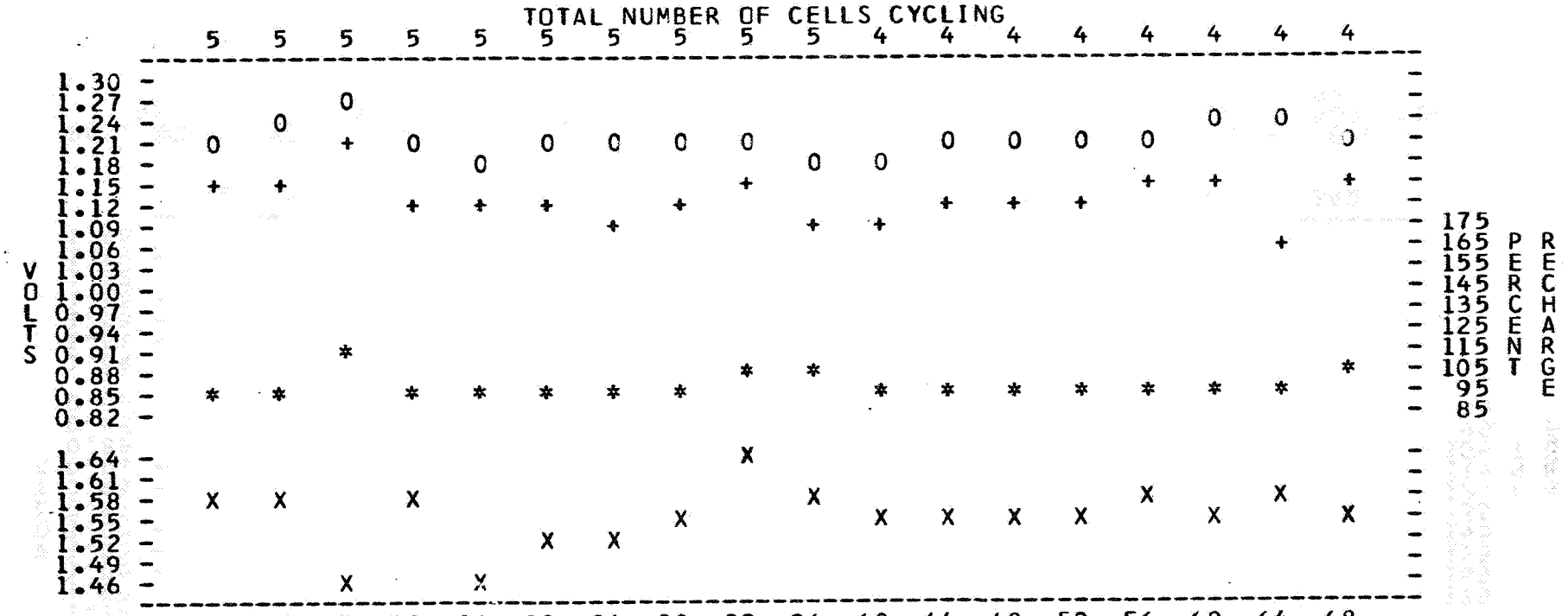
STATUS CELLS CYCLING 5
CYCLES COMPLETED 11089

CAPACITY CHECK CYCLES
1300, 2907, 4088, 5419, 6745
8233, 9638,

FIGURE 14(A) (CONTD)

QE/C 69-244

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 3925

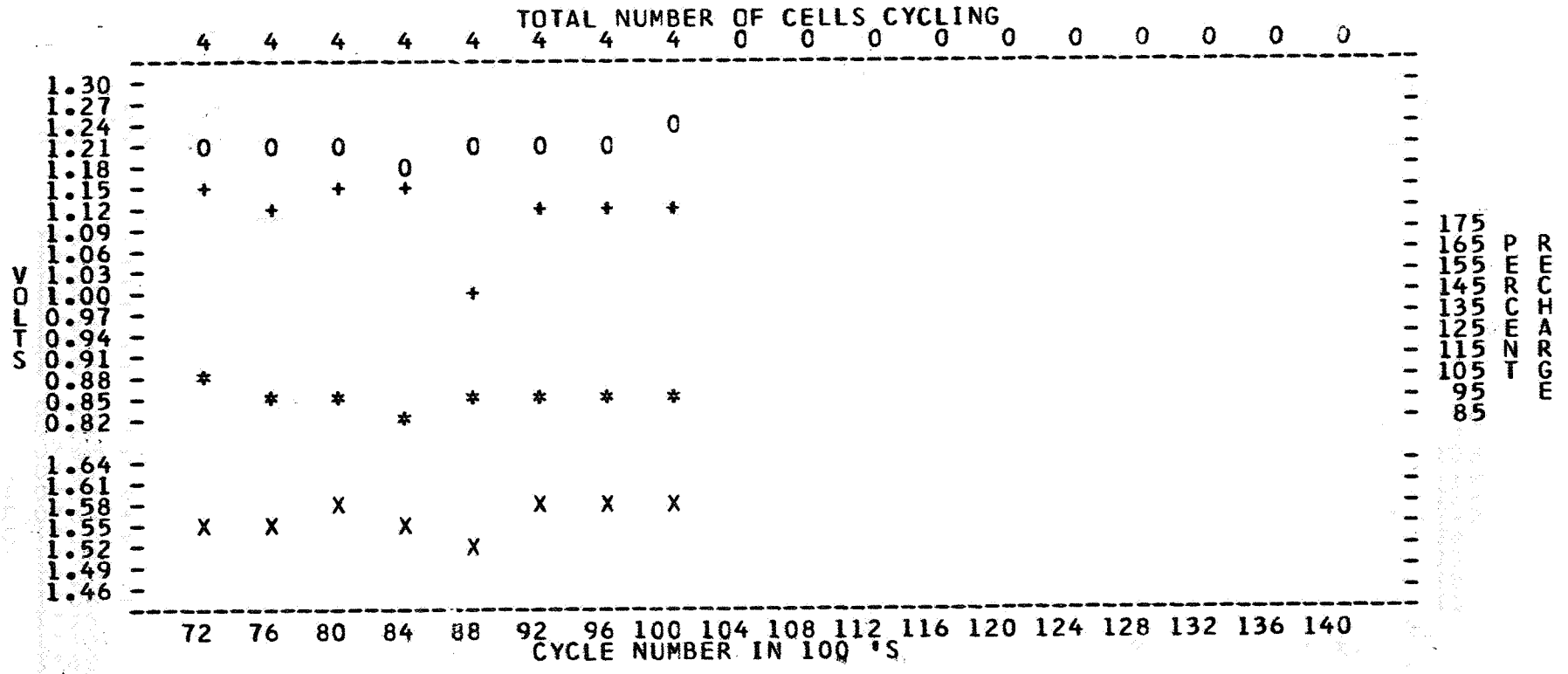
PACK NUMBER 075D
TYPE OF CELLS GULTON 3.50 AH
TEST TEMPERATURE -20 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 40 PERCENT
SPECIFIED CHARGE RATE 1.54 AMP.

STATUS CELLS CYCLING 4
CYCLES COMPLETED 9866

CAPACITY CHECK CYCLES
1190, 2679, 3860, 4196, 5521
7008, 8418, 9826,

FIGURE 14(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 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.

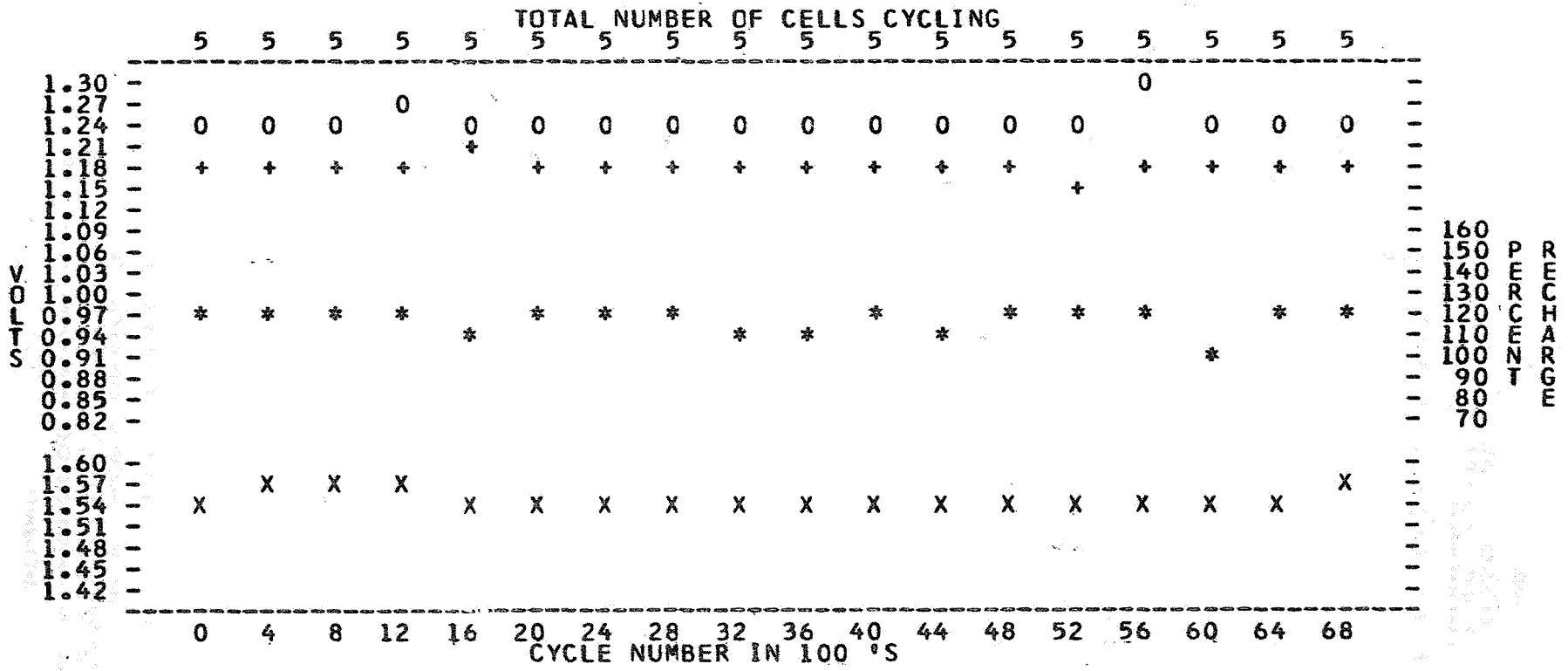
STATUS CELLS CYCLING 4
CYCLES COMPLETED 9866

CAPACITY CHECK CYCLES
1190, 2679, 3860, 4196, 5521
7008, 8418, 9826,

FIGURE 14(B) (CONTD)

QE/C 69-244

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 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.

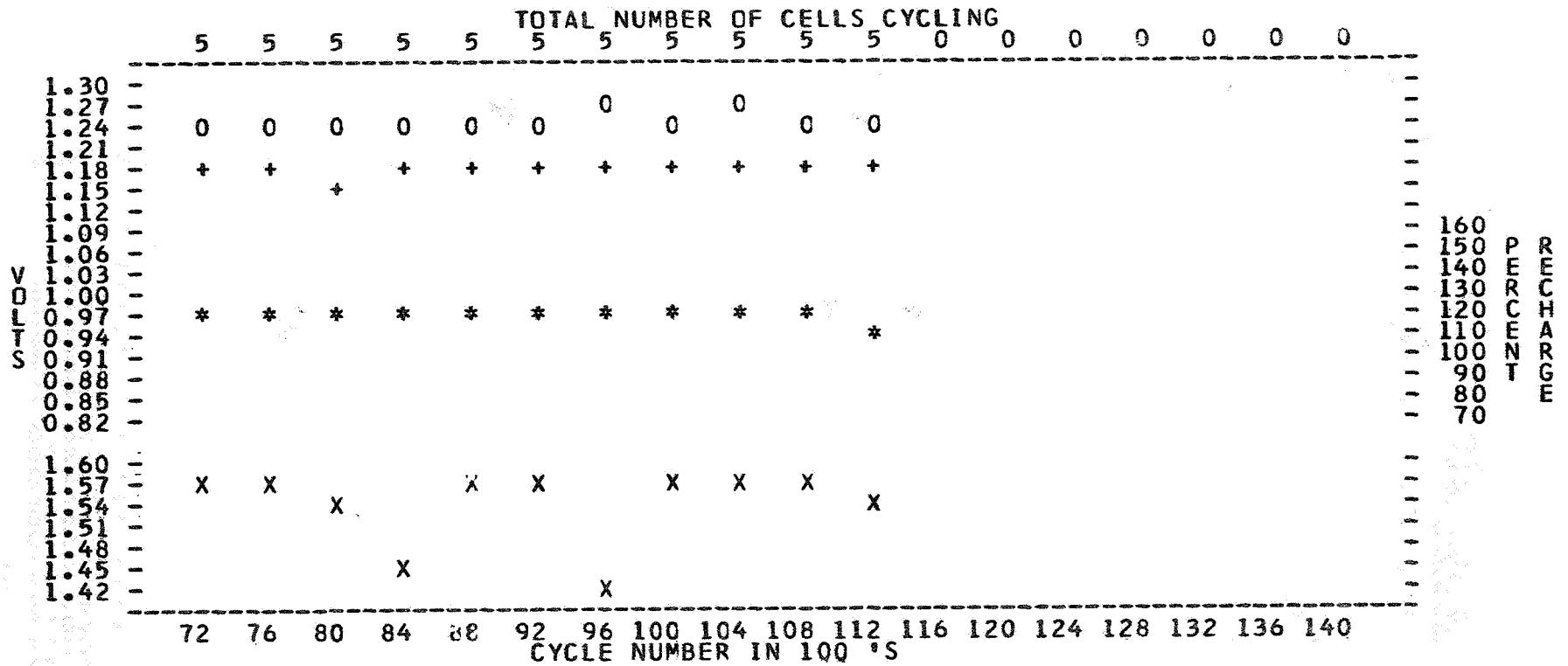
STATUS CELLS CYCLING 5
CYCLES COMPLETED 11168

CAPACITY CHECK CYCLES
1427, 2911, 4014, 5421, 6794
8233, 9656,11050,

FIGURE 14(C)

QE/C 69-244

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 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.

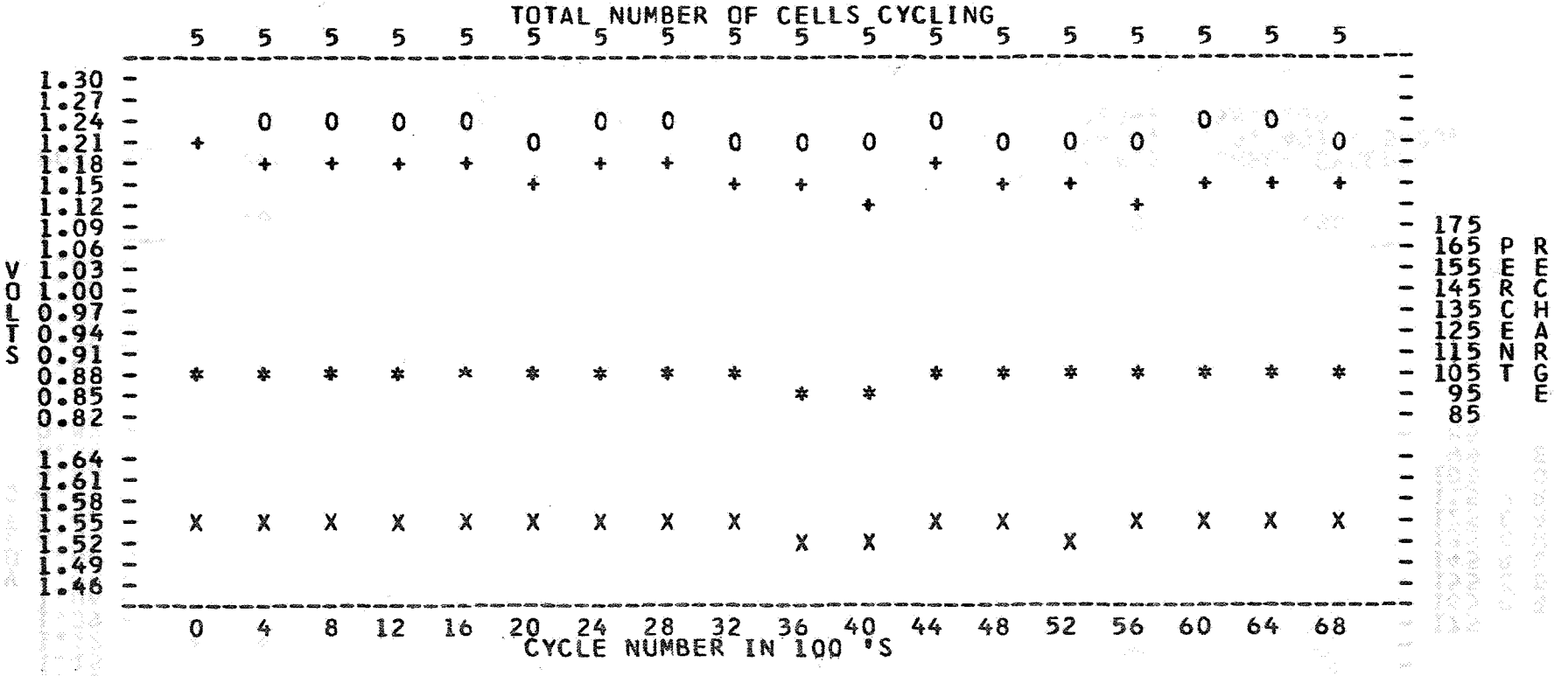
STATUS CELLS CYCLING 5
CYCLES COMPLETED 11168

CAPACITY CHECK CYCLES
1427, 2911, 4014, 5421, 6794
8233, 9656, 11050,

FIGURE 14(C) (CONTD)

QE/C 69-244

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 099C
TYPE OF CELLS GULTON 3.50 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 40 PERCENT
SPECIFIED CHARGE RATE 1.61 AMP.

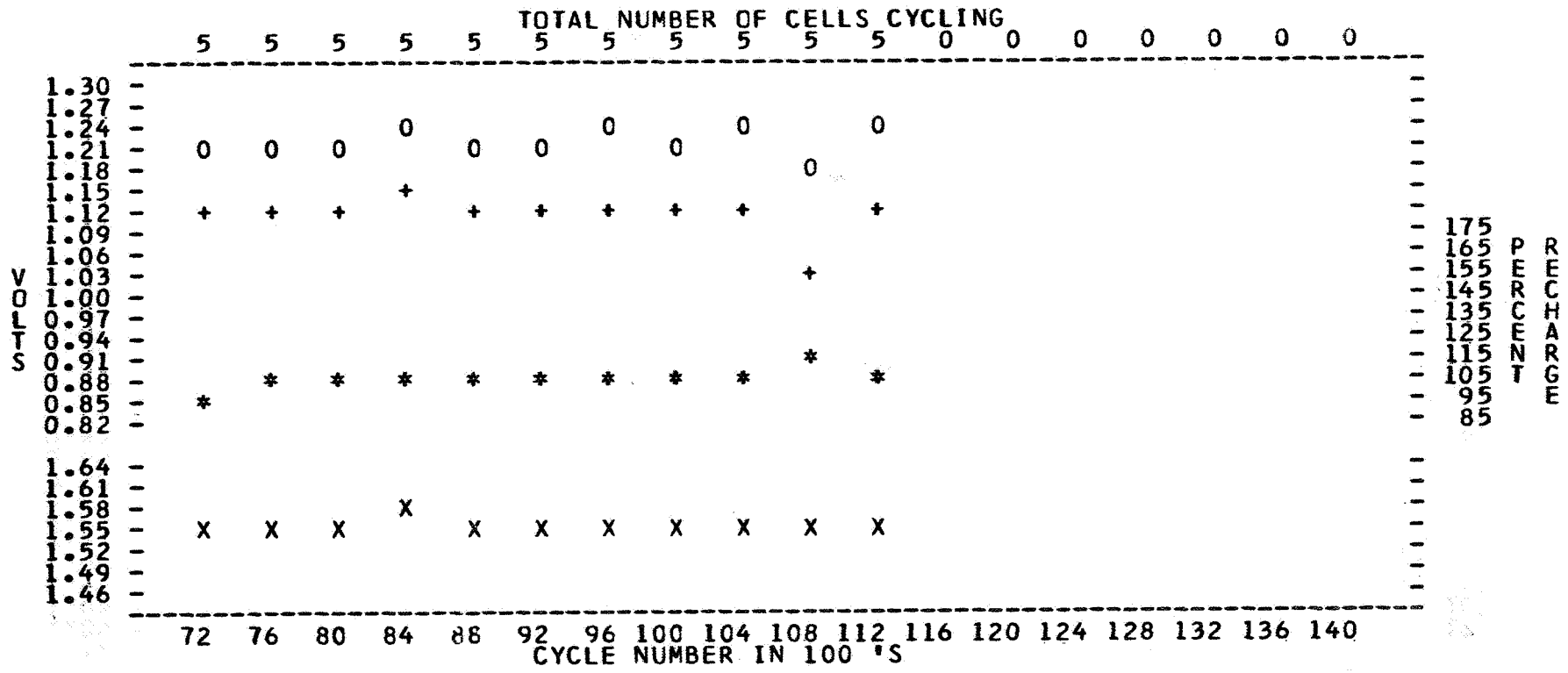
STATUS CELLS CYCLING 5
CYCLES COMPLETED 11088

CAPACITY CHECK CYCLES
1426, 2910, 4013, 5420, 6793
8234, 9658,11047,

FIGURE 14(D)

QE/C 69-244

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 099C
TYPE OF CELLS GULTON 3.50 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 40 PERCENT
SPECIFIED CHARGE RATE 1.61 AMP.

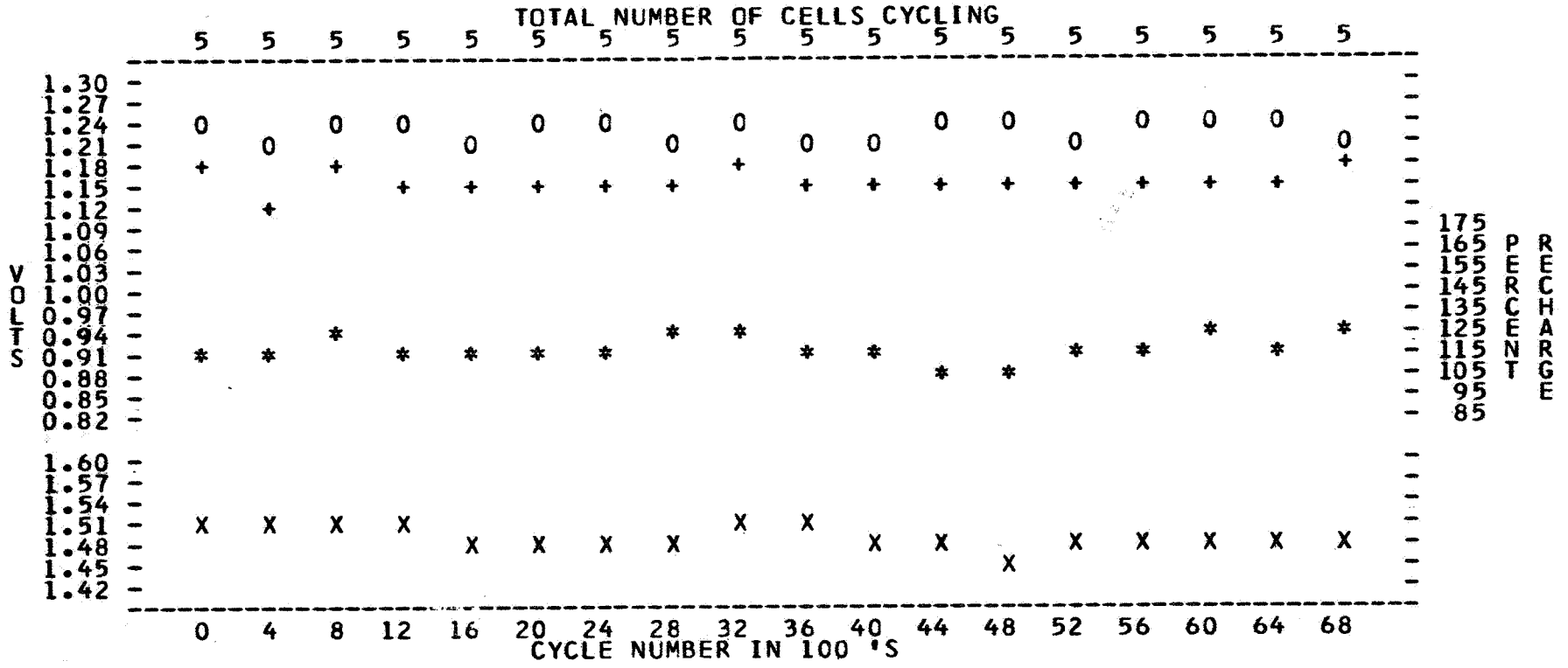
STATUS CELLS CYCLING 5
CYCLES COMPLETED 11088

CAPACITY CHECK CYCLES
1426, 2910, 4013, 5420, 6793
8234, 9658,11047,

FIGURE 14(D) (CONTD)

QE/C 69-244

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 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.

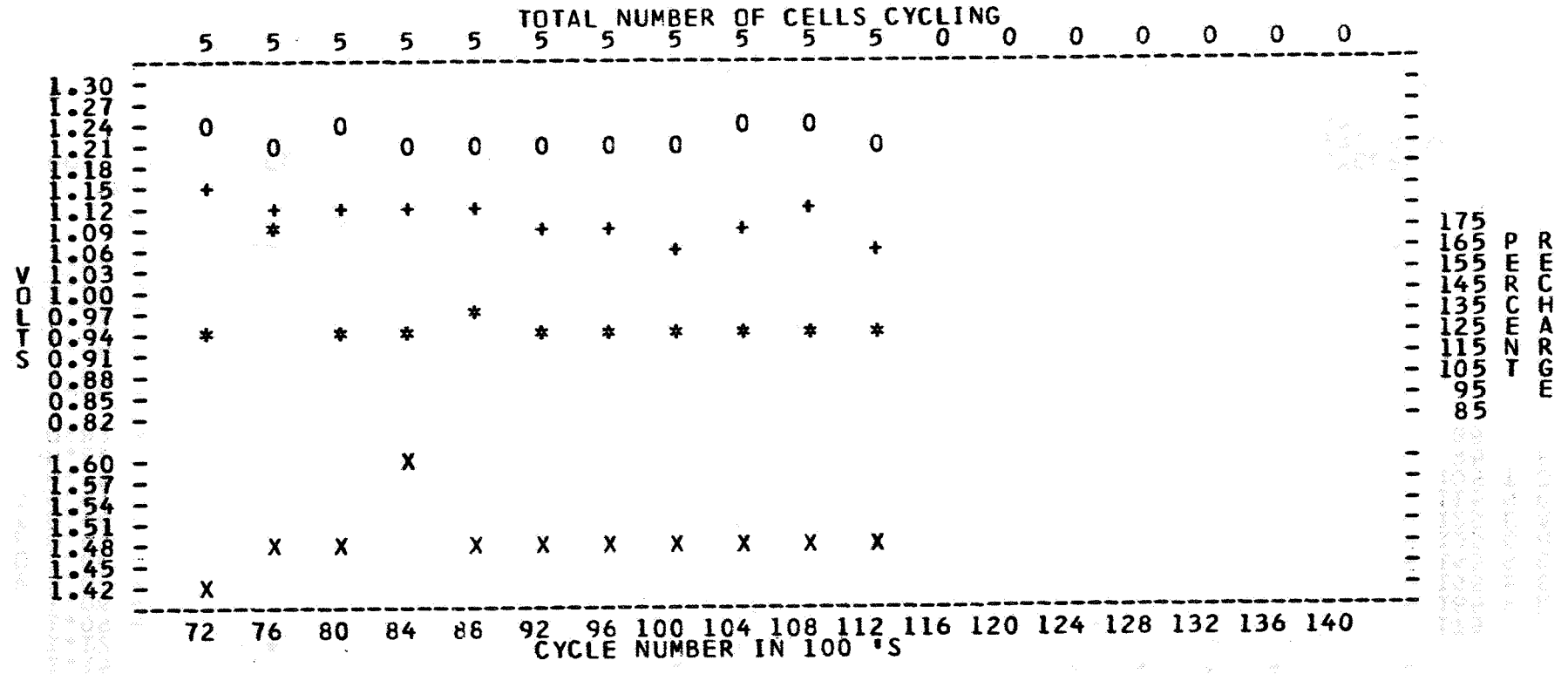
STATUS CELLS CYCLING 5
CYCLES COMPLETED 11185

CAPACITY CHECK CYCLES
1442, 2928, 3999, 5438, 6814
8254, 9678,11063,

FIGURE 14(E)

QE/C 69-244

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 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.

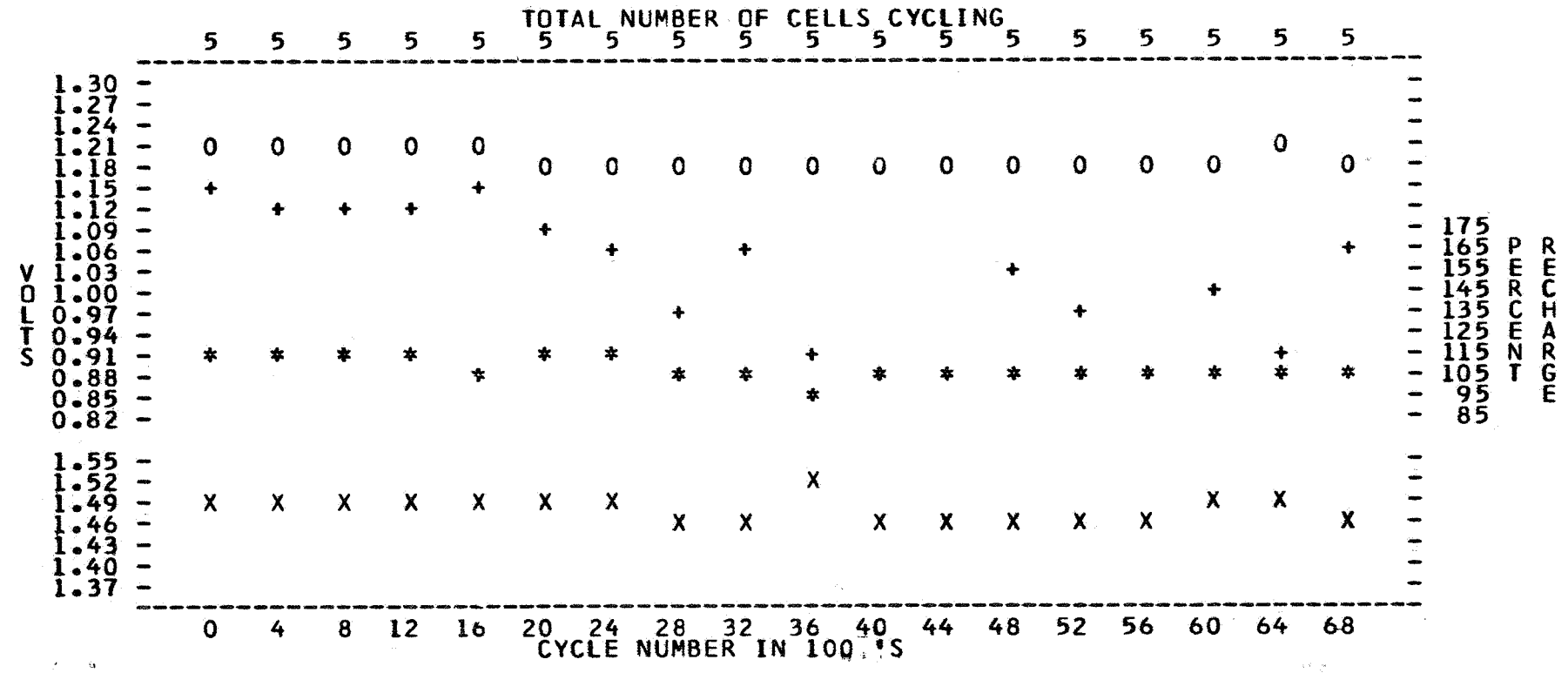
STATUS CELLS CYCLING 5
CYCLES COMPLETED 11185

CAPACITY CHECK CYCLES
1442, 2928, 3999, 5438, 6814
8254, 9678,11063,

FIGURE 14(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

QE/C 69-244



POS. NO.	CYCLE FAILED
03	8940
02	9406
01	9978

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.

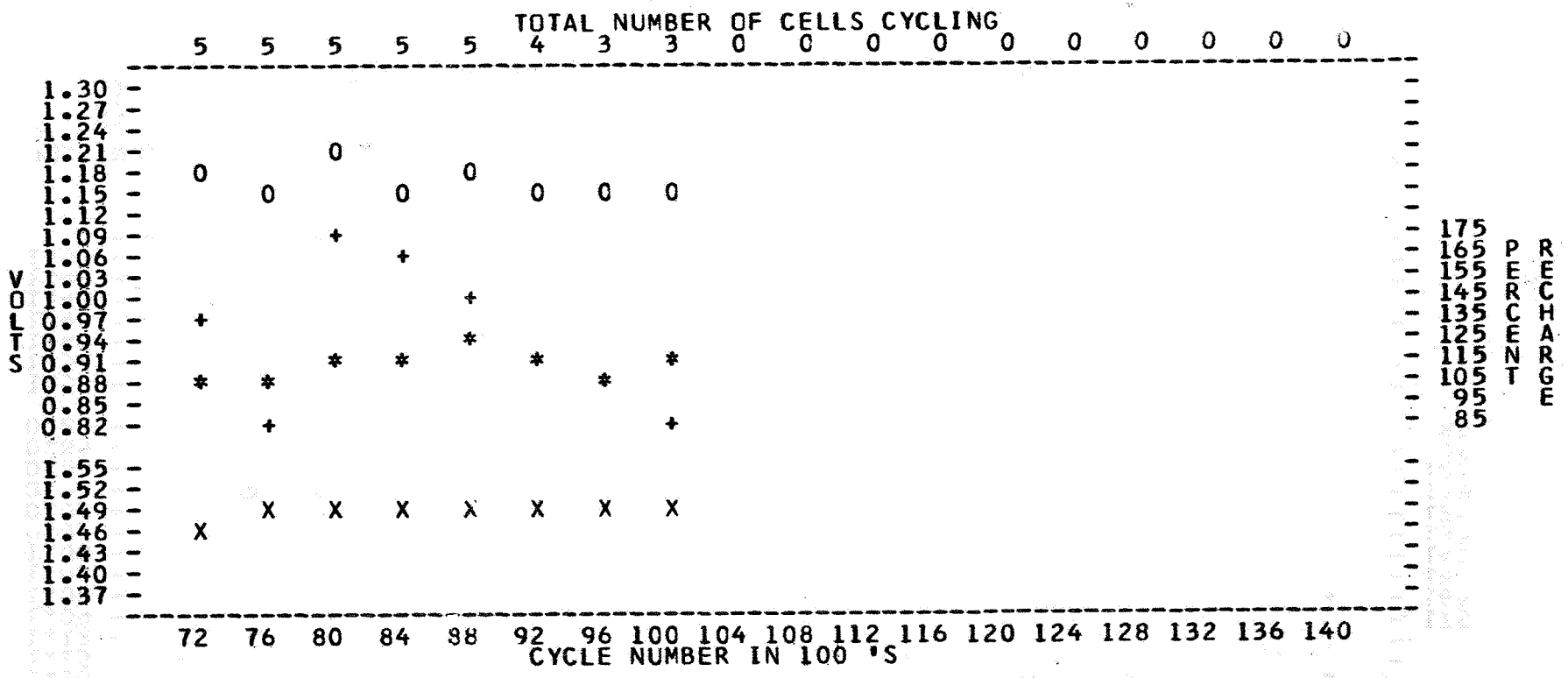
CAPACITY CHECK CYCLES
1442, 2928, 3999, 5441, 6815
8221, 9551,

STATUS PACK FAILED
ON CYCLE NUMBER 9978

FIGURE 14(F)

QE/C 69-244

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
03	8940
02	9406
01	9978

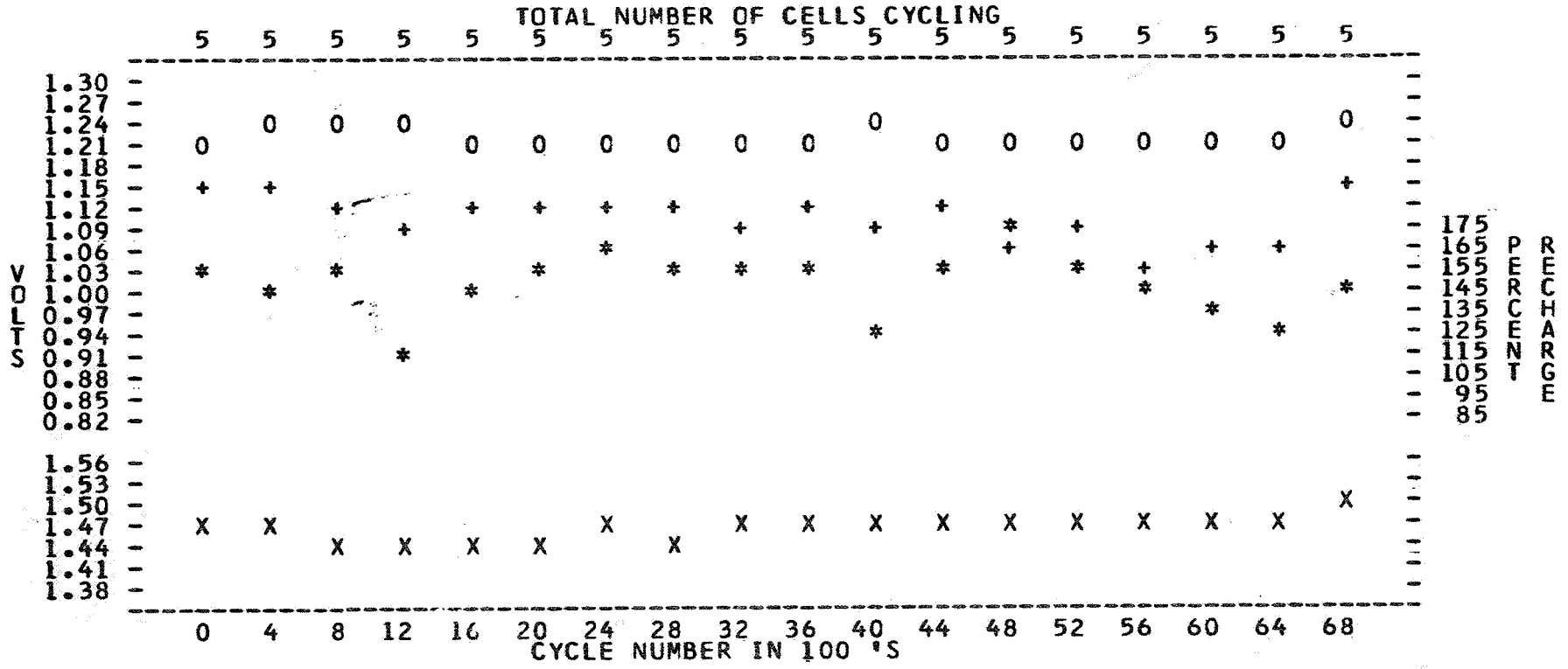
PACK NUMBER 073C
TYPE OF CELLS GULTON 3.50 AH
TEST TEMPERATURE 25 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 40 PERCENT
SPECIFIED CHARGE RATE 1.75 AMP.

STATUS PACK FAILED
ON CYCLE NUMBER 9978

CAPACITY CHECK CYCLES
1442, 2928, 3999, 5441, 6815
8221, 9551,

FIGURE 14(F) (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



POS. NO.	CYCLE FAILED
01	9392
04	10536

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.

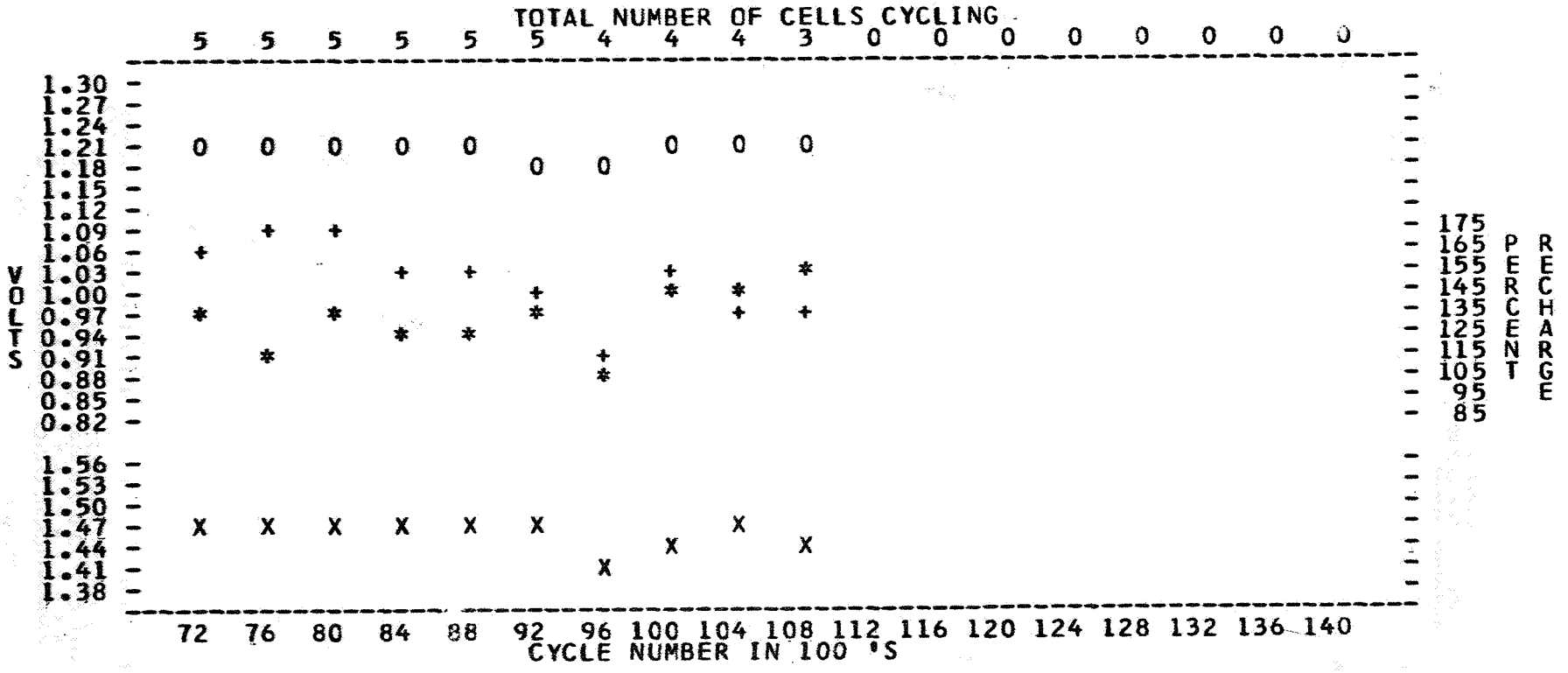
STATUS CELLS CYCLING 3
CYCLES COMPLETED 10865

CAPACITY CHECK CYCLES
1473, 1650, 2866, 4274, 5792
7168, 8572, 9837,

FIGURE 14(G)

QE/C 69-244

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	9392
04	10536

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.

STATUS CELLS CYCLING 3
CYCLES COMPLETED 10865

CAPACITY CHECK CYCLES
1473, 1650, 2866, 4274, 5792
7168, 8572, 9837,

FIGURE 14(G) (CONTD)

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 15(A) through 15(D).) Cycling was started in August 1964. Packs 115B, 126B and 4B have each completed over 24,000 cycles to date with no cell failures. Packs 14B, 28B and 40B failed on cycles 8474, 20,227 and 10,360 respectively with a total of 10 cell failures. Some leakage occurred in each of the six packs.

(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 126B: 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 occurred under the epoxy potting. All three failed cells showed signs of high internal pressure, migration of negative plate material and separator deterioration. Welds between the terminals and the positive plate tabs of two of these cells were weak.

(f) Pack 40B: There was leakage under the epoxy potting. The four failed cells showed signs of migration of negative plate material and separator deterioration. These same cells had weak welds between the positive plate tabs and the terminals. One cell developed an internal short.

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

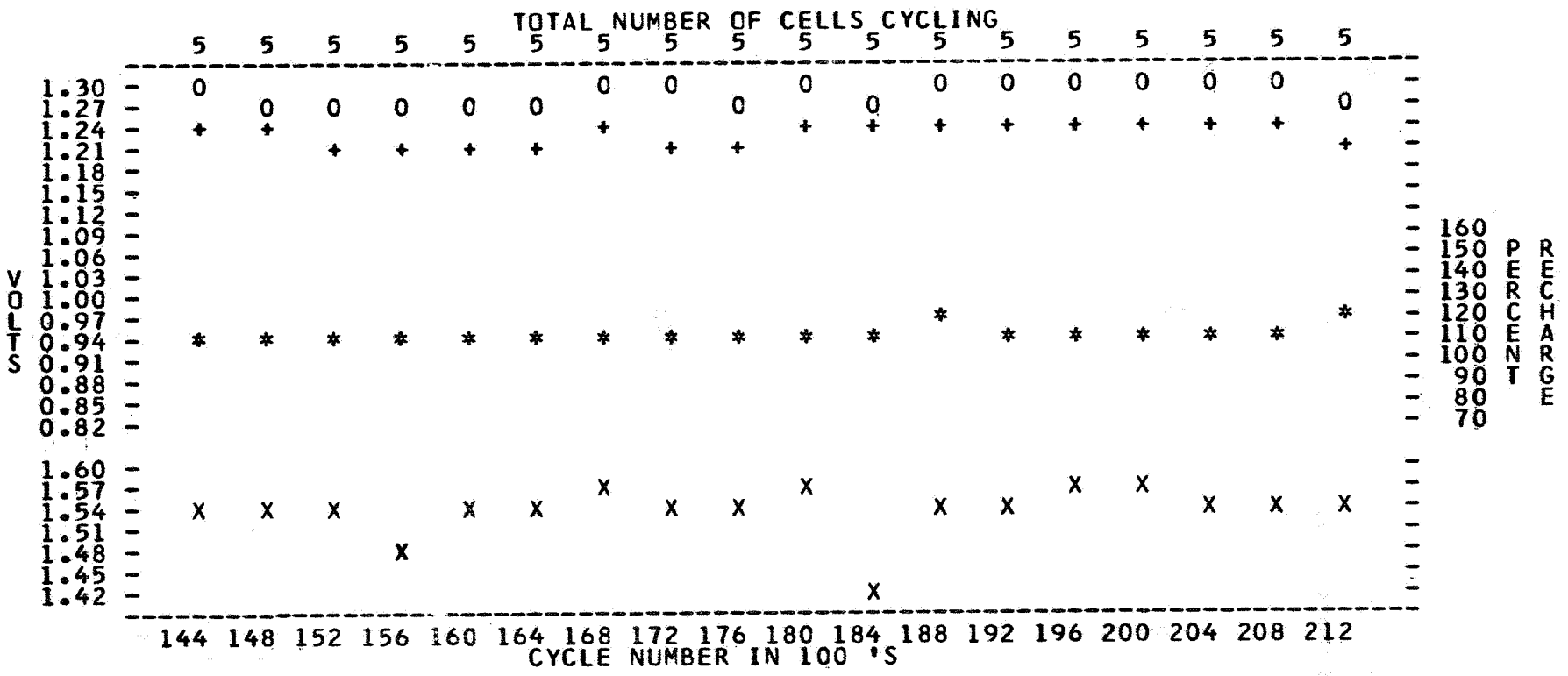
PRECYCLING AND CAPACITY CHECKS

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
Precycling 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 F	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 F
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	
880 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	3.40	2.97	1.17		0.32	
	Disch #2	3.67	3.37	1.30		0.47	
1232 Days	Disch #1	3.03	2.93	1.43		1.30	
	Disch #2	3.50	3.37	1.70		2.10	
1320 Days	Disch #1	2.96	2.87	1.20		1.30	
	Disch #2	3.63	3.27	1.47		1.73 F	
1408 Days	Disch #1	3.20	3.10	1.27			
	Disch #2	3.47	3.33	1.50			

F - 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

QE/C 69-244



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.

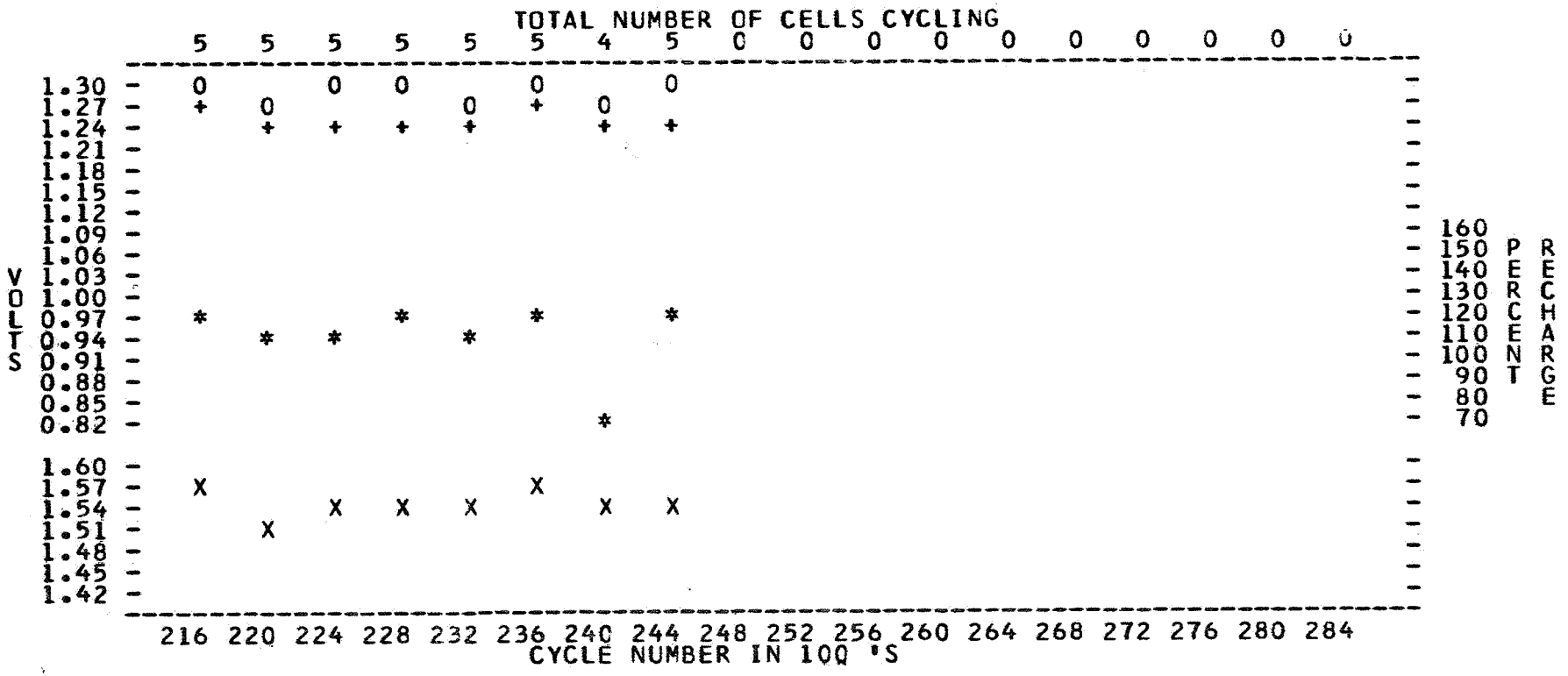
STATUS CELLS CYCLING 5
CYCLES COMPLETED 24307

CAPACITY CHECK CYCLES
1669, 3149, 4346, 5553, 6783
8310, 9900,11692,13680,15278
16573,17983,19386,20841,22232
23593, 0, 0, 0, 0

FIGURE 15(A)
136

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

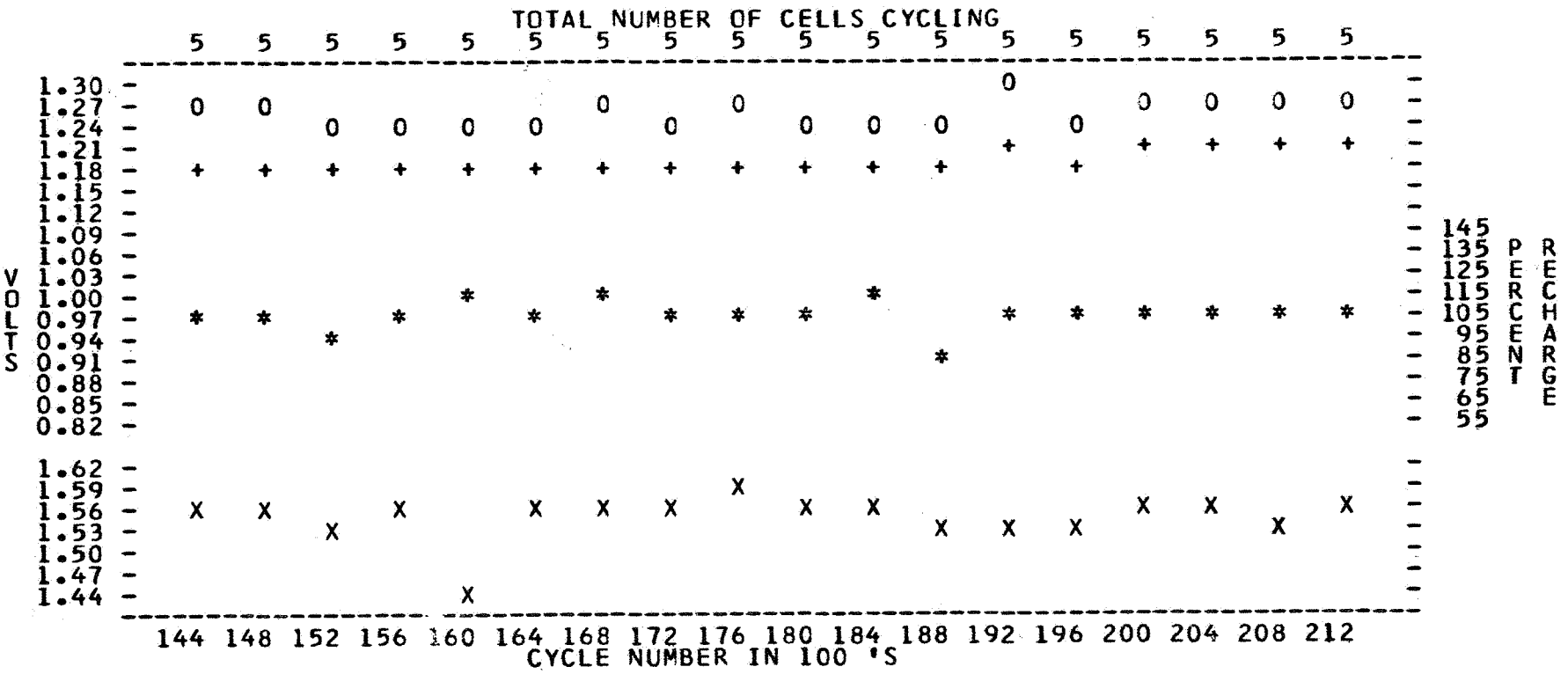
PACK NUMBER 1158
TYPE OF CELLS GULTON 4.00 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 15 PERCENT
SPECIFIED CHARGE RATE 0.69 AMP.

STATUS CELLS CYCLING 5
CYCLES COMPLETED 24307

CAPACITY CHECK CYCLES
1669, 3149, 4346, 5553, 6783
8310, 9900,11692,13680,15278
16573,17983,19386,20841,22232
23593, 0, 0, 0, 0

FIGURE 15(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



POS. NO. CYCLE FAILED

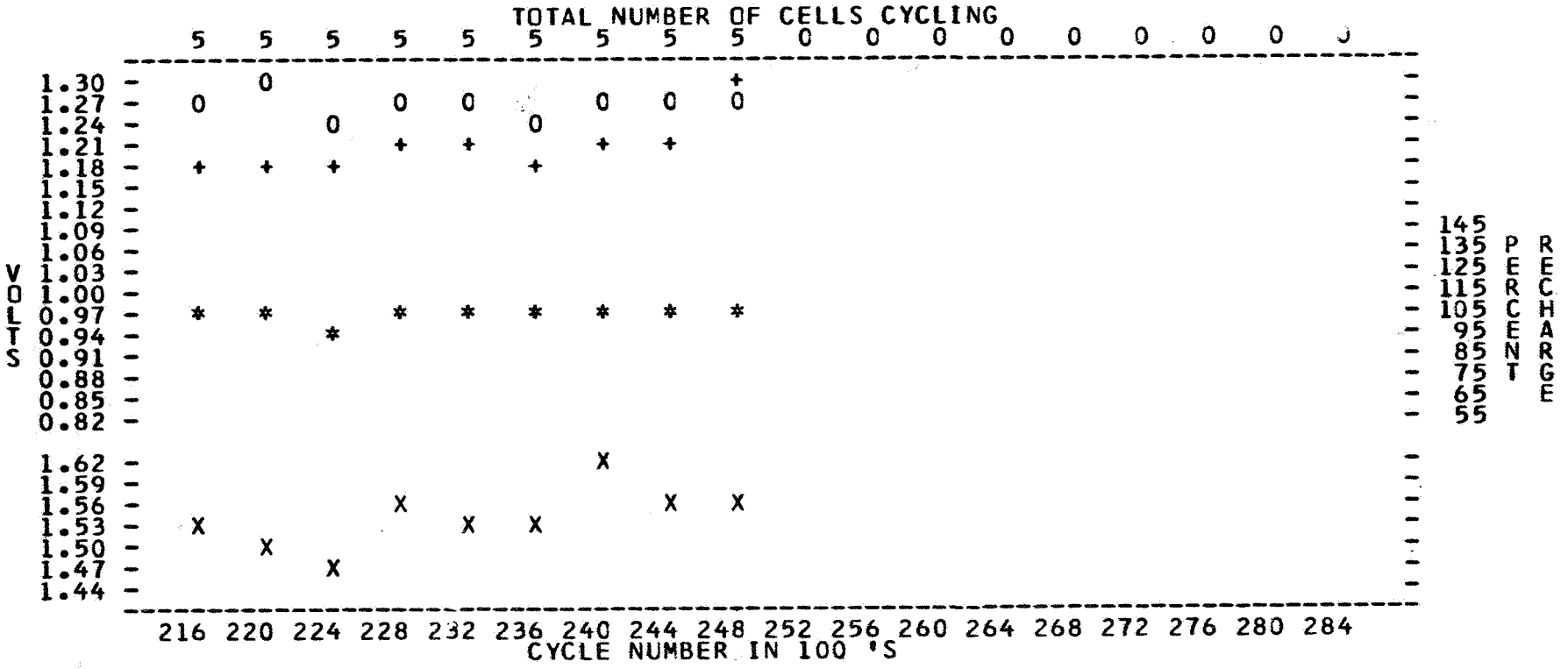
PACK NUMBER 126B
TYPE OF CELLS GULTON 4.00 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 1.15 AMP.

STATUS CELLS CYCLING 5
CYCLES COMPLETED 24756

CAPACITY CHECK CYCLES
1669, 3149, 4545, 6625, 8192
9819,11180,12908,14562,15968
17231,18670,19963,21341,22746
24076, 0, 0, 0, 0

FIGURE 15(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. 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.

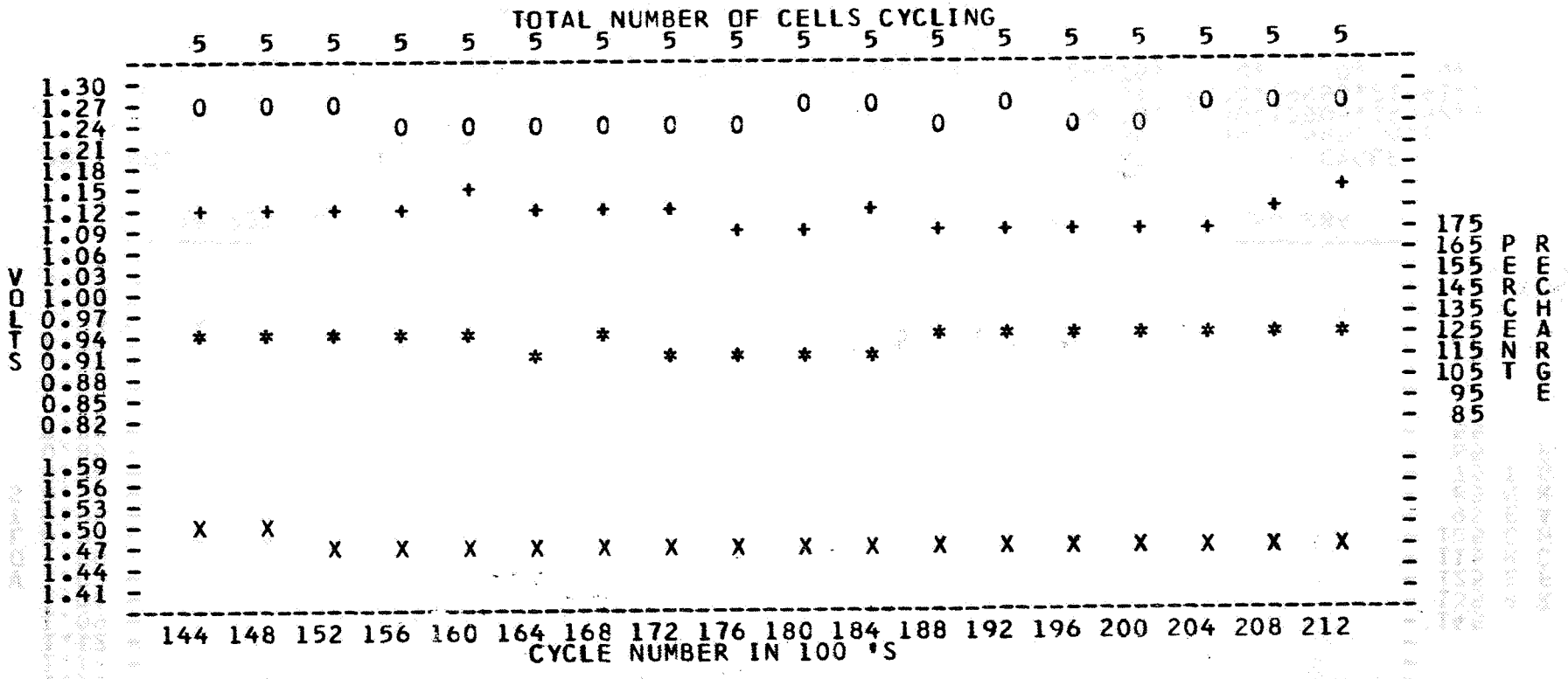
CAPACITY CHECK CYCLES
1669, 3149, 4545, 6625, 8192
9819,11180,12908,14562,15968
17231,18670,19963,21341,22746
24076, 0, 0, 0, 0

STATUS CELLS CYCLING 5
CYCLES COMPLETED 24756

FIGURE 15(B)

IJT2231

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 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.

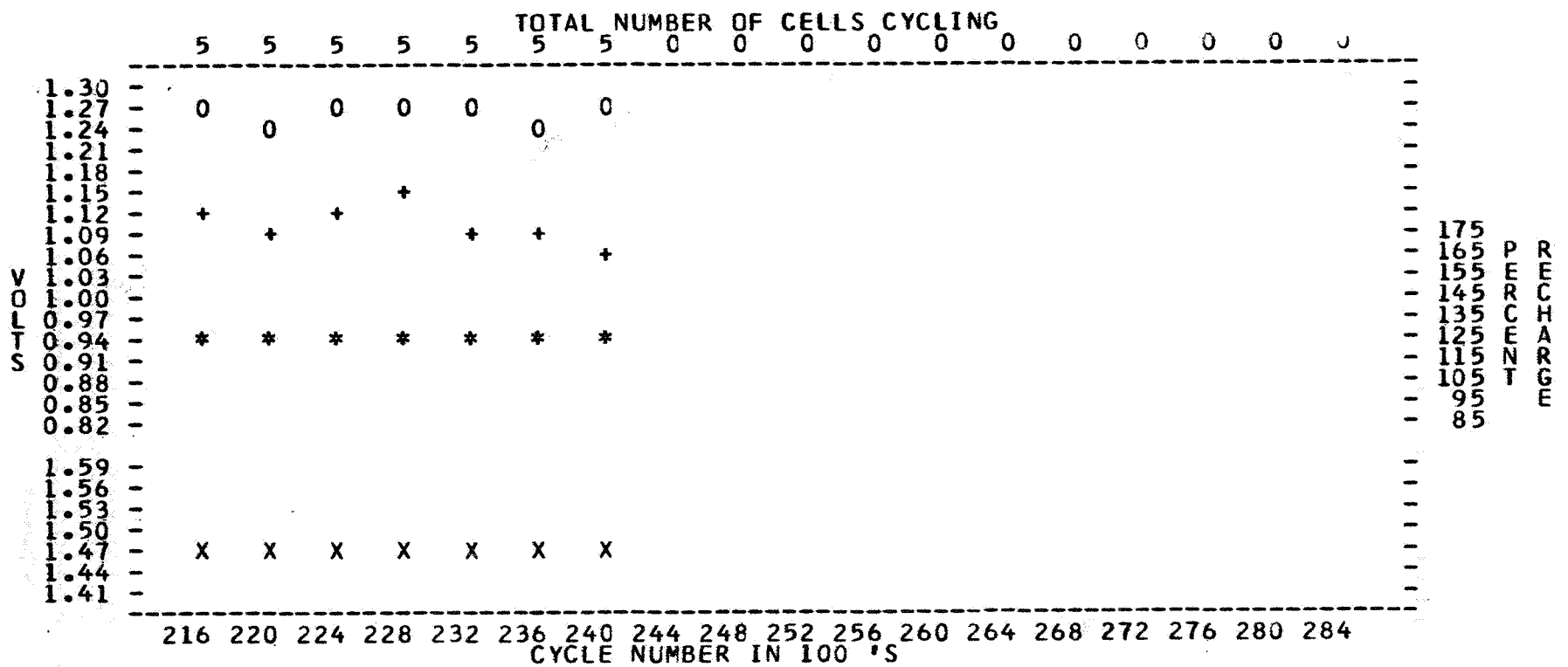
STATUS CELLS CYCLING 5
CYCLES COMPLETED 24476

CAPACITY CHECK CYCLES
1484, 2880, 4271, 5933, 7142
8692,10317,11637,13622,14997
15174,16387,17794,19279,20622
22029,23434, 0, 0, 0

FIGURE 15(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 69-244



POS. NO. CYCLE FAILED

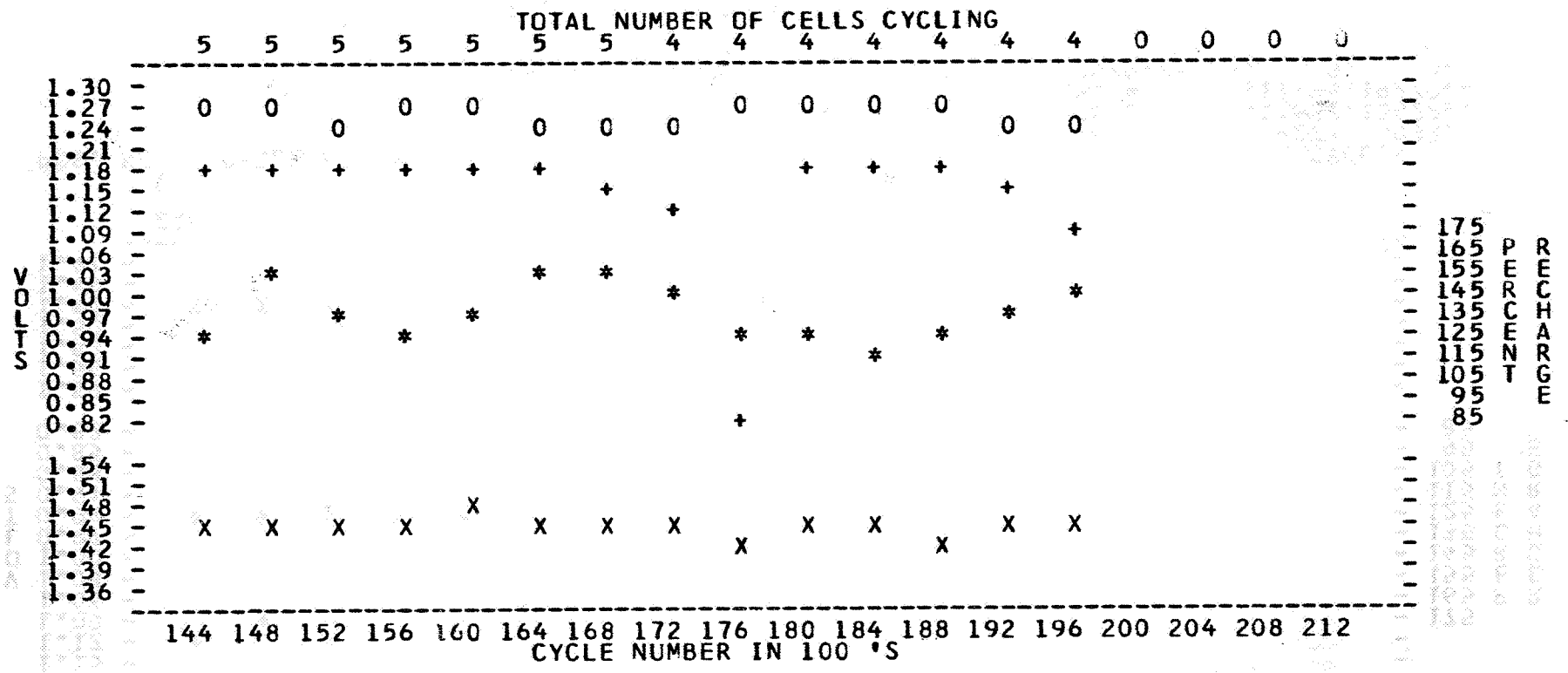
PACK NUMBER 0048
TYPE OF CELLS GULTON 4.00 AH
TEST TEMPERATURE 25 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 1.25 AMP.

STATUS CELLS CYCLING 5
CYCLES COMPLETED 24476

CAPACITY CHECK CYCLES
1484, 2880, 4271, 5933, 7142
8692,10317,11637,13622,14997
15174,16387,17794,19279,20622
22029,23434, 0, 0, 0

FIGURE 15(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



POS. NO.	CYCLE FAILED
01	17021
03	20227
04	20227

PACK NUMBER 028B
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.

CAPACITY CHECK CYCLES
1483, 2881, 4254, 5610, 6724
8441, 9993, 11448, 13260, 14405
14507, 15611, 17019, 18362, 19801
0, 0, 0, 0, 0

STATUS PACK FAILED
ON CYCLE NUMBER 20227

FIGURE 15(D)

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 manufactured to the NIMBUS specifications.

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 16(A) through 16(C).) Cycling was started in May 1965. Packs 117A, 121A and 120A have each completed over 19,000 cycles to date with none, two and one cell failures respectively. Packs 118B, 127A and 128A failed on cycles 8108, 10,638 and 6345 respectively with a total of nine cell failures.

(a) Pack 121A: One failed cell showed separator deterioration and migration of negative plate material. The separator of the other failed cell was short (vertical height); the cell

contained extraneous positive material between the plates and separator and had some leakage as evidenced by a deposit.

(b) Pack 120A: The one failed cell showed separator deterioration and migration of negative plate material.

(c) Pack 118B: The three failed cells showed separator deterioration, migration of negative plate material, and burned positive tabs. Welds between the terminals and positive plate tabs of two of these cells were weak as was the weld between the negative plate tab to case of one cell. Two cells had some leakage as evidenced by a deposit on one, and a 2.0 gram weight loss in the other.

(d) Pack 127A: The three failed cells showed separator deterioration of which two also showed migration of negative plate material. Ceramic shorts and leaks as evidenced by deposits occurred with two cells. There was one instance of a weak weld of the positive tab to the terminal, and one with the separator pierced by the positive tab to termianl weld. One cell had high pressure.

(e) Pack 128A: The three failed cells showed separator deterioration of which two also showed migration of negative plate material. Ceramic shorts and leaks as evidenced by deposits occurred with two cells. There was one instance of a weak weld between the negative plate tab to case, and one with the separator pierced by the positive tab to terminal weld.

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

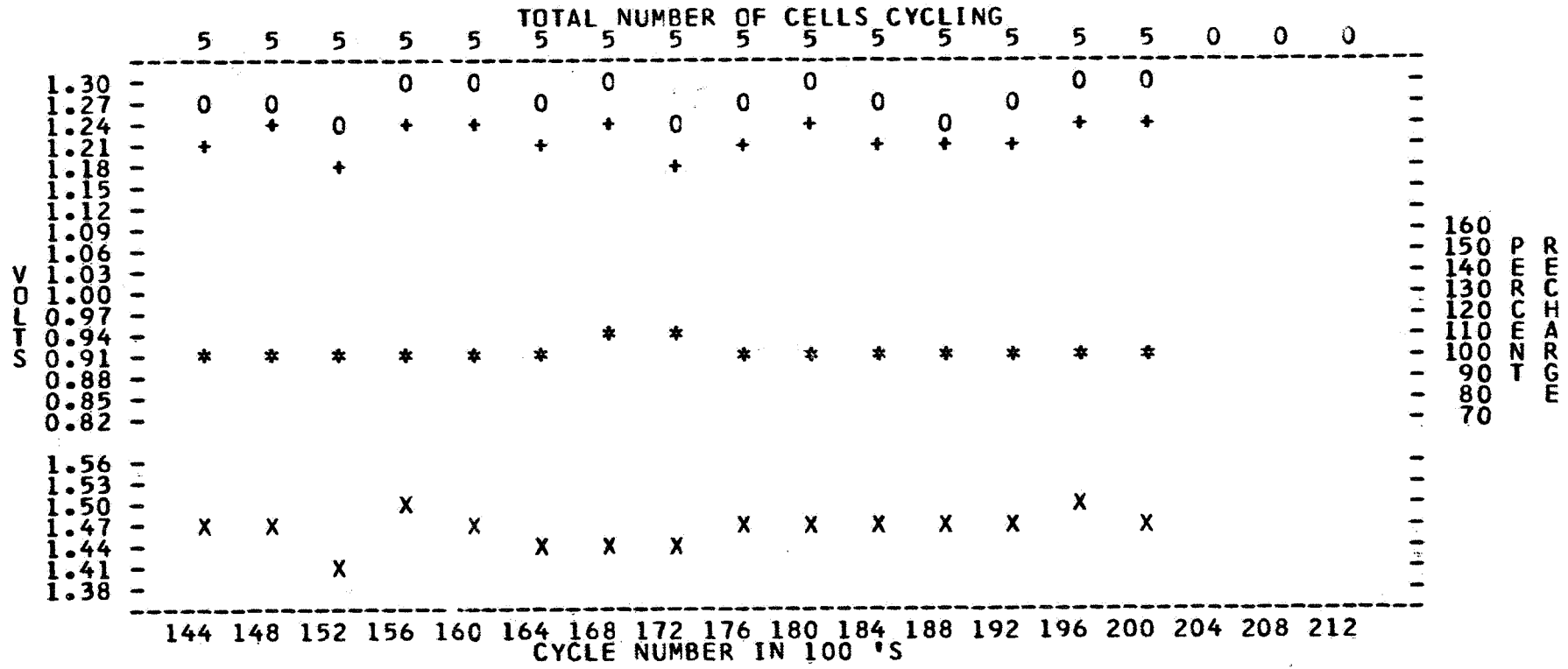
PRECYCLING AND CAPACITY CHECKS

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
Precycling 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 F
440 Days	Disch #1	4.33	3.42	1.75	1.13	1.25	
	Disch #2	4.75	4.29	2.08	2.00 F	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 F	
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			
880 Days	Disch #1	3.42	2.63	2.25			
	Disch #2	4.04	3.96	3.00			
968 Days	Disch #1	3.67	2.92	2.04			
	Disch #2	4.17	3.79	2.58			
1056 Days	Disch #1	2.96	1.88	1.46			
	Disch #2	4.04	3.83	2.37			
1144 Days	Disch #1	3.37	2.29	1.46			
	Disch #2	3.83	3.67	2.37			
1232 Days	Disch #1			1.33			
	Disch #2			2.42			

* Missed Capacity Check
F - Failed

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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.

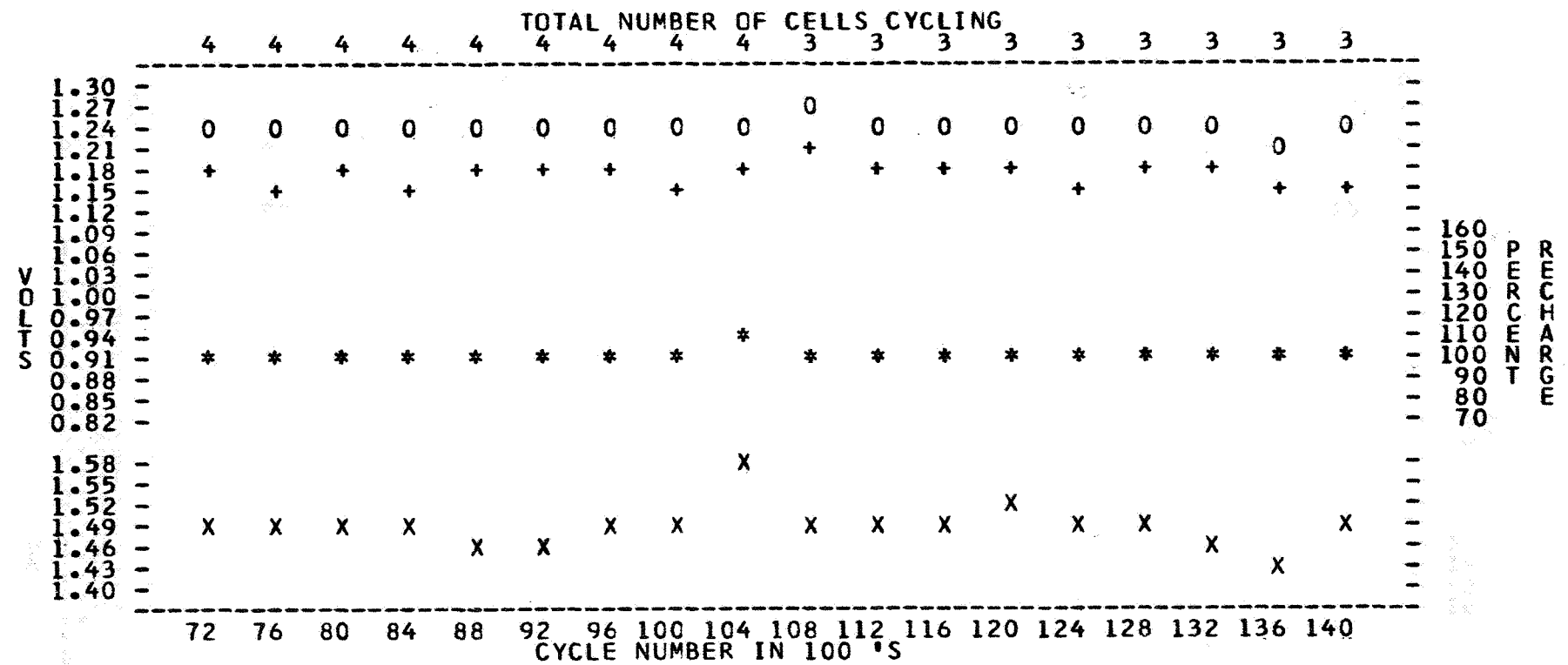
STATUS CELLS CYCLING 5
CYCLES COMPLETED 20051

CAPACITY CHECK CYCLES
1721, 2967, 4517, 6100, 7369
9270,10539,10790,11973,13412
14817,16195,17600,19007,

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.	CYCLE FAILED
01	6694
04	10803

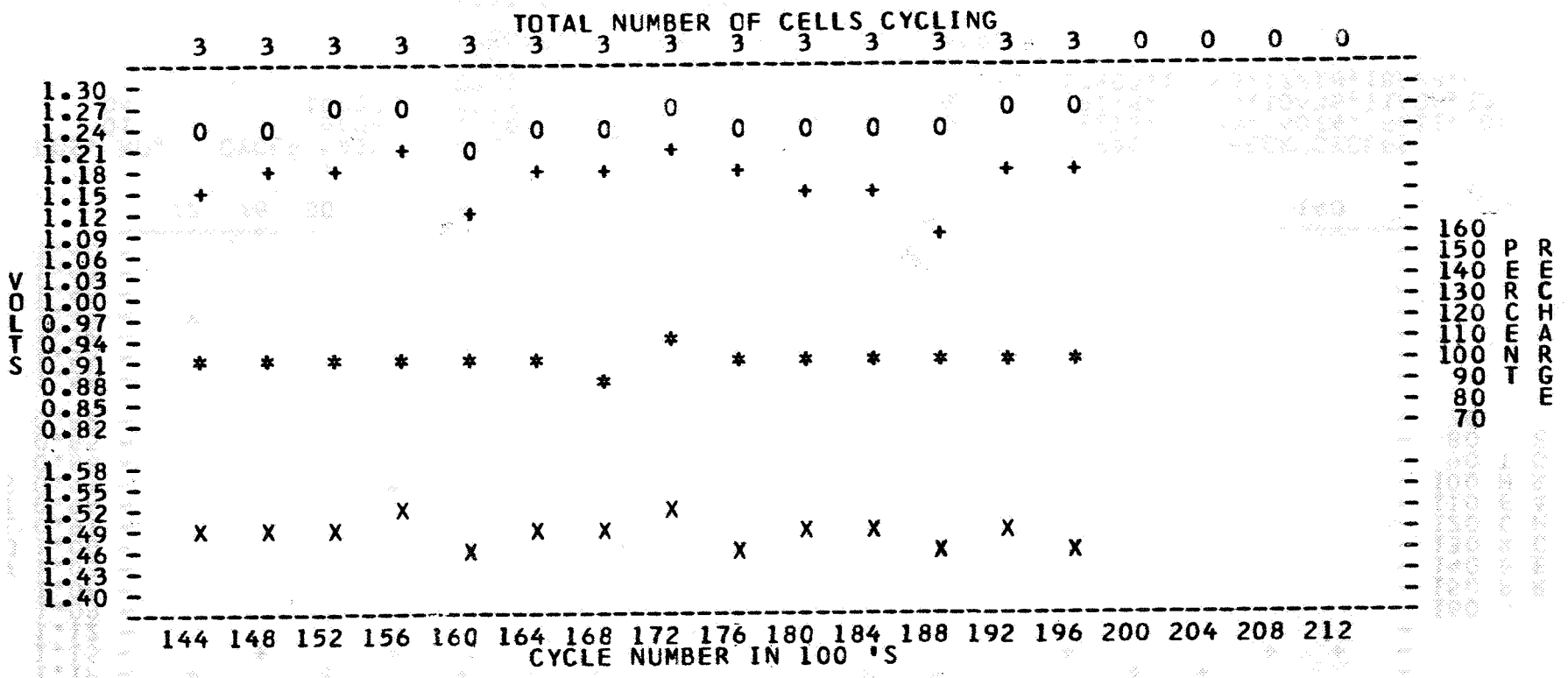
PACK NUMBER 121A
TYPE OF CELLS GULTON 5.00 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 1.38 AMP.

STATUS CELLS CYCLING 3
CYCLES COMPLETED 19642

CAPACITY CHECK CYCLES
1278, 2524, 4074, 5611, 6819
8778,10185,10436,11606,13112
14483,15893,17218,18628,

FIGURE 16(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



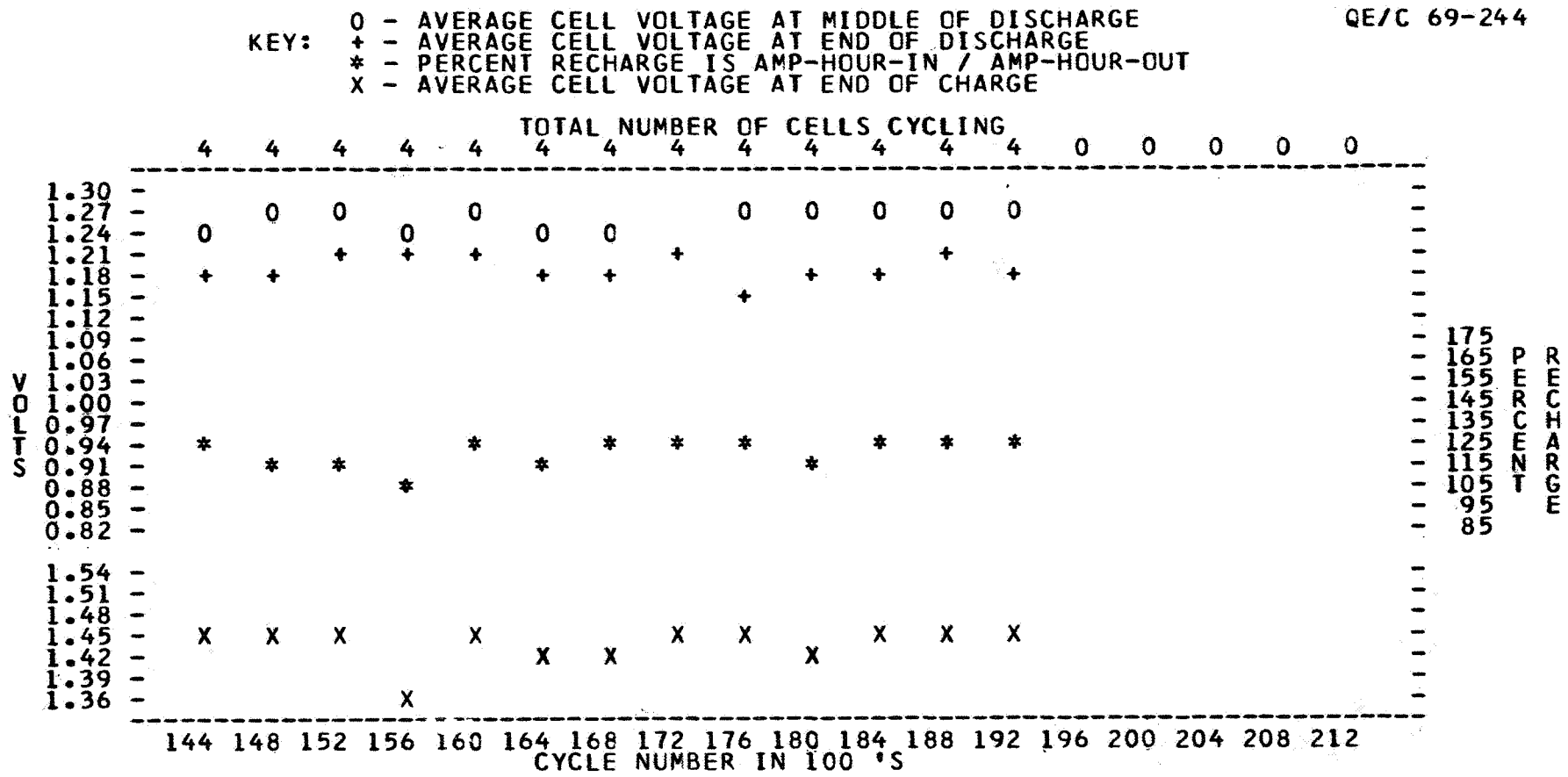
POS. NO.	CYCLE FAILED
01	6694
04	10803

PACK NUMBER 121A
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.

STATUS CELLS CYCLING 3
CYCLES COMPLETED 19642

CAPACITY CHECK CYCLES
1278, 2524, 4074, 5611, 6819
8778,10185,10436,11606,13112
14483,15893,17218,18628,

FIGURE 16(B) (CONTD)



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 19096

CAPACITY CHECK CYCLES
1854, 3101, 4731, 6231, 7551
12220,13407,14868,14783,16274
17679,19086,

FIGURE 16(C)

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 container and the cell cover 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 17). 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 18(A) through 18(E).) Cycling was started in December 1965. Packs 44B, 32B, 100B and 90C have each completed over 16,000 cycles to date with a total of only two cell failures. One cell failure occurred under each of

the -20° and 0° C test conditions in cells with nonfolded seals. 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. Packs 76B, 96C, 42B and 30B failed on cycles 11,158, 9791, 3798 and 1275 respectively with a total of 12 cell failures. Under each of the two test conditions, Packs 76B and 42B with folded seals had longer cycle lives than did their respective comparison Packs 96C and 30B with nonfolded seals.

(a) Pack 32B: The one failed cell showed separator deterioration, migration of negative plate material and leakage at the terminal and the welded seam. The positive plate tab was burned, and the weld between the positive tab and the terminal was weak.

(b) Pack 90C: The one failed cell showed separator deterioration, migration of negative plate material, and leakage at the terminal as evidenced by a deposit.

(c) Pack 76B: The three failed cells showed separator deterioration, and all leaked around the welded cover to case seam with a weight loss per cell up to 6 grams. One cell leaked around the terminal. The positive tab of one cell was burned.

(d) Pack 96C: The three failed cells showed separator deterioration and migration of negative plate material. The positive tab of each was burned, and the three cells leaked around the welded seam and one around the terminal as evidenced by deposits or weight loss. The weld of the negative tab to case was weak.

(e) Pack 42B: The three failed cells showed separator deterioration and migration of negative plate material; and each leaked around the terminal and welded seam as evidenced by deposits and weight loss per cell up to 4.2 grams. The positive tab of two cells was burned. Two cells had a weak weld between the negative plate tab and the case.

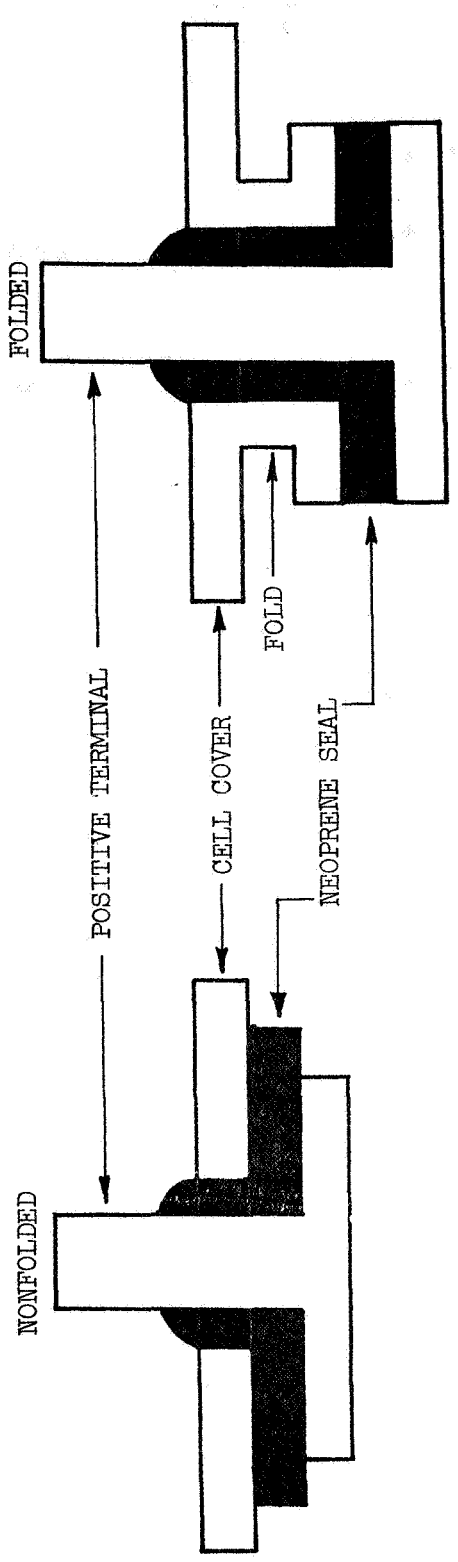
(f) Pack 30B: The three failed cells showed separator deterioration, two of which also showed migration of the negative plate material. The three cells leaked as evidenced by a deposit on the seam of one cell, and a weight loss of each of the three cells from 1.0 to 2.2 grams. The positive tab of two cells was burned, and two cells had high internal pressure. One cell had a weak weld between the positive tab and the terminal.

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

PRECYCLING 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
Precycling Capacity		4.01	4.53	6.25	6.58	5.60	6.30	4.39	4.90 F
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	4.39	4.66	1.45	2.05	1.35	
	Disch #2	4.34	4.67	4.85	5.50	1.59	2.24	1.35 F	
264 Days	Disch #1	2.10	2.10	4.06	4.71	1.35	1.49		
	Disch #2	3.36	3.64	4.39	5.27	1.59	1.87		
352 Days	Disch #1	2.43	2.47	3.87	4.29	1.40	2.10		
	Disch #2	3.36	3.45	4.25	4.85	1.63	2.85		
440 Days	Disch #1	3.22	2.52	3.45	3.69	1.91	1.73		
	Disch #2	3.64	3.64	3.83	4.48	2.10	2.33		
528 Days	Disch #1	2.29	2.10	3.31	3.13	1.31	1.49		
	Disch #2	3.27	3.27	3.64	3.97	1.49	2.38 F		
616 Days	Disch #1	2.24	2.10	3.13	3.08	1.26			
	Disch #2	3.41	3.17	3.50	3.64	1.17 F			
704 Days	Disch #1	2.24	1.49	2.89	2.57				
	Disch #2	4.48	2.99	2.75	3.27				
792 Days	Disch #1	2.85	1.59	2.47	2.38				
	Disch #2	3.87	2.85	2.75	3.08				
880 Days	Disch #1			2.33	1.96				
	Disch #2			2.61	2.75				
968 Days	Disch #1				1.12				
	Disch #2				2.57				

F - Failed

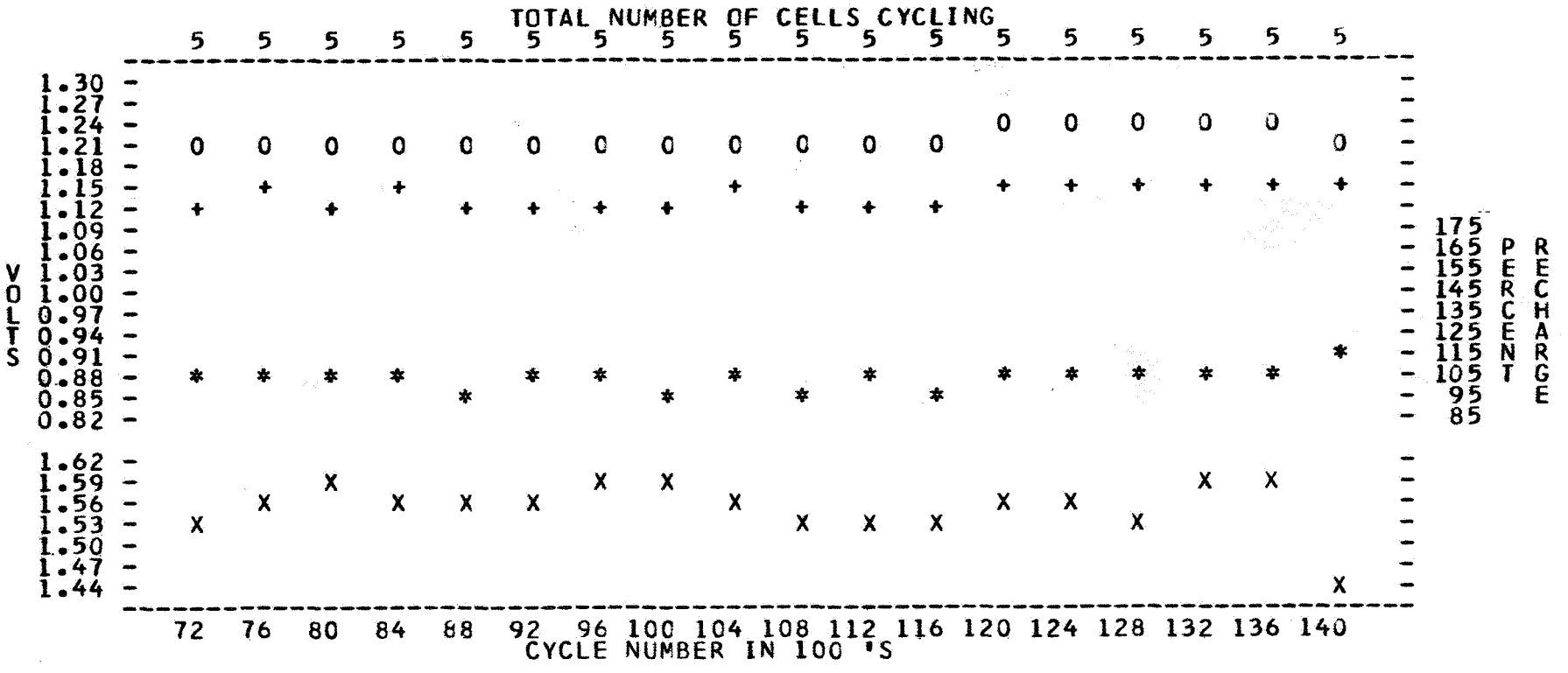


CROSS SECTION OF NEOPRENE SEAL

FIGURE 17

QE/C 69-244

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

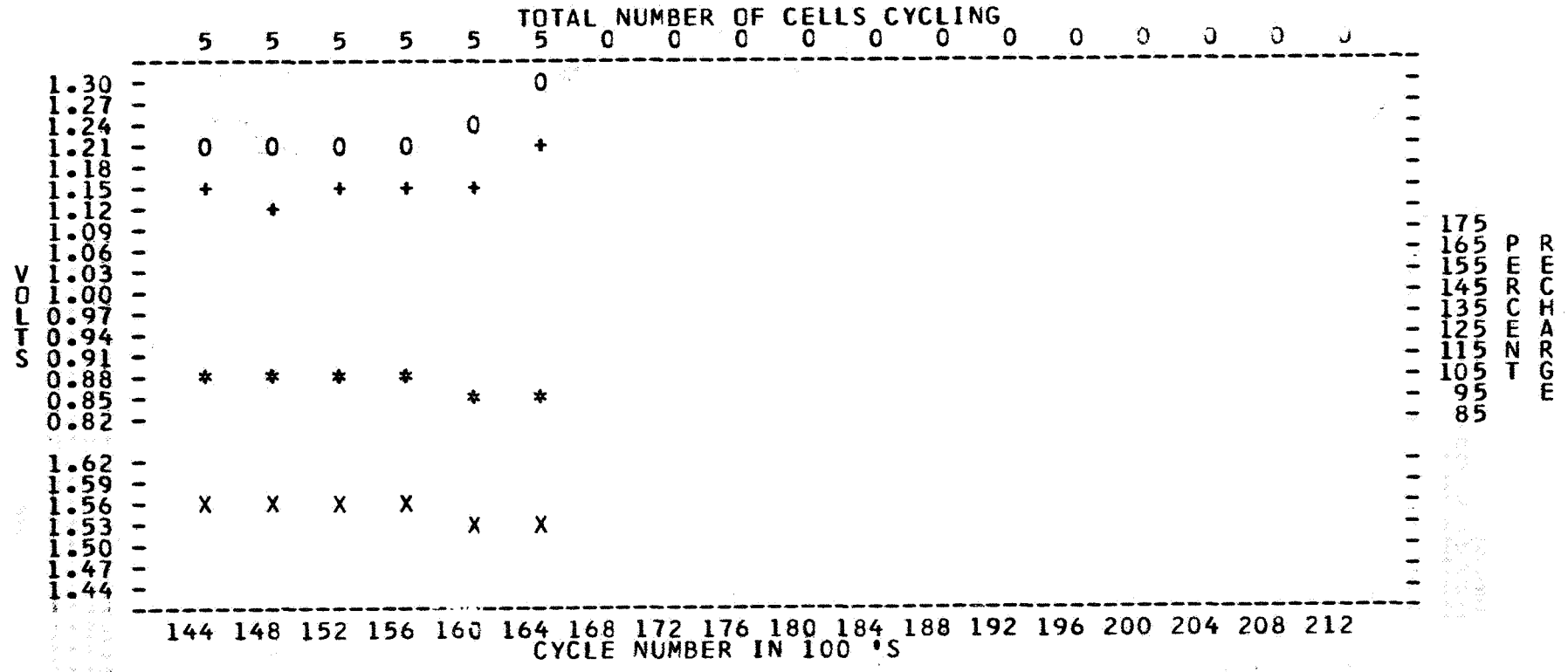
PACK NUMBER 044B
TYPE OF CELLS GULTON 5.60 AH
TEST TEMPERATURE -20 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 1.61 AMP.

STATUS CELLS CYCLING 5
CYCLES COMPLETED 16579

CAPACITY CHECK CYCLES
2696, 4047, 6304, 8606, 10239
11645, 13082, 14345, 15755,

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



POS. NO. CYCLE FAILED

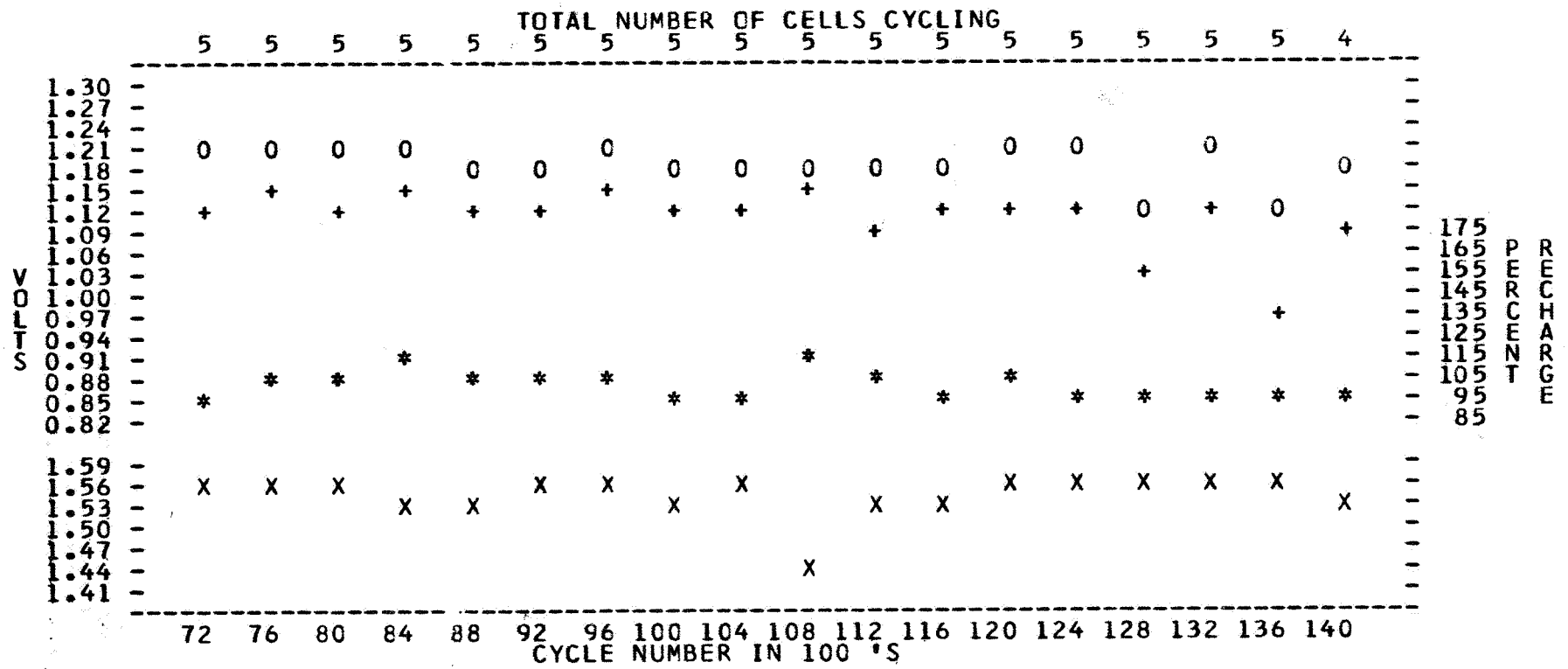
PACK NUMBER 044B
TYPE OF CELLS GULTON 5.60 AH
TEST TEMPERATURE -20 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 1.61 AMP.

CAPACITY CHECK CYCLES
2696, 4047, 6304, 8606, 10239
11645, 13082, 14345, 15755,

STATUS CELLS CYCLING 5
CYCLES COMPLETED 16579

FIGURE 18(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



POS. NO. 02 — CYCLE FAILED 13846

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.

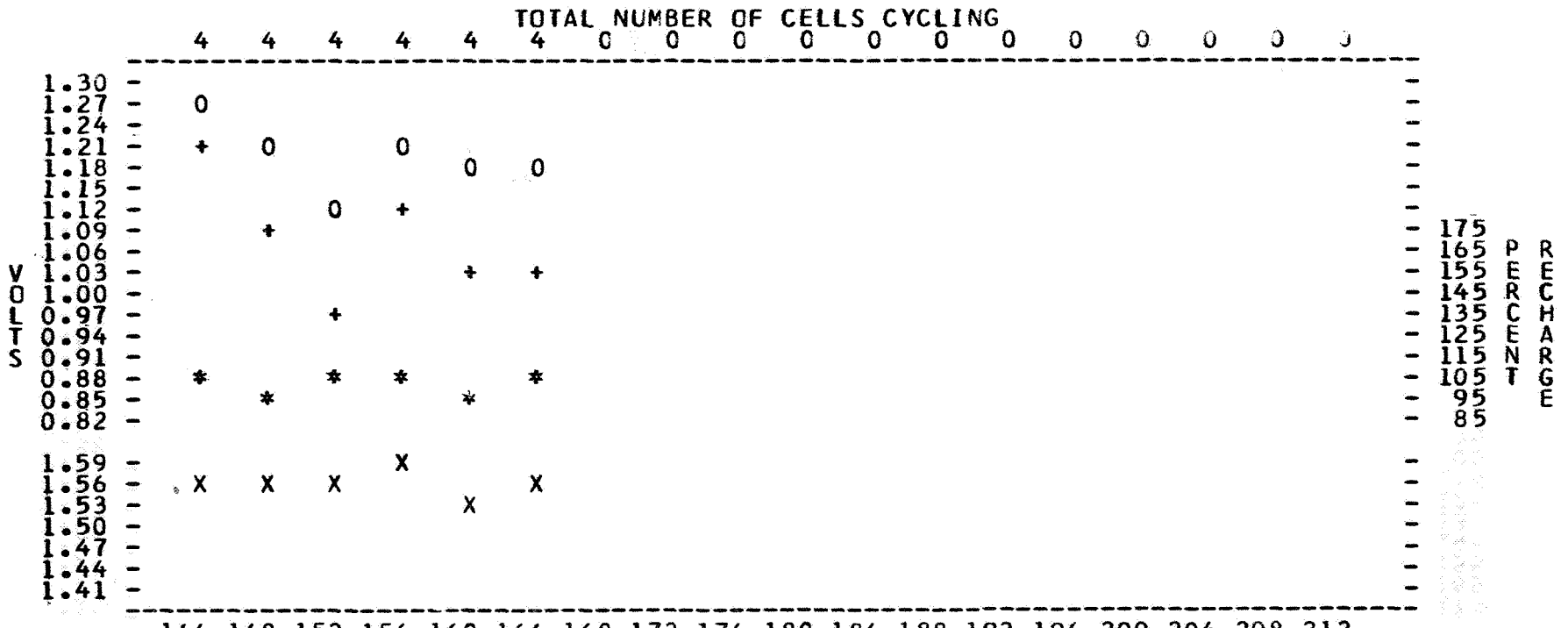
STATUS CELLS CYCLING 4
CYCLES COMPLETED 16473

CAPACITY CHECK CYCLES
2696, 4031, 6288, 8423, 9766
11143,12549,14050,15459,

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 13846

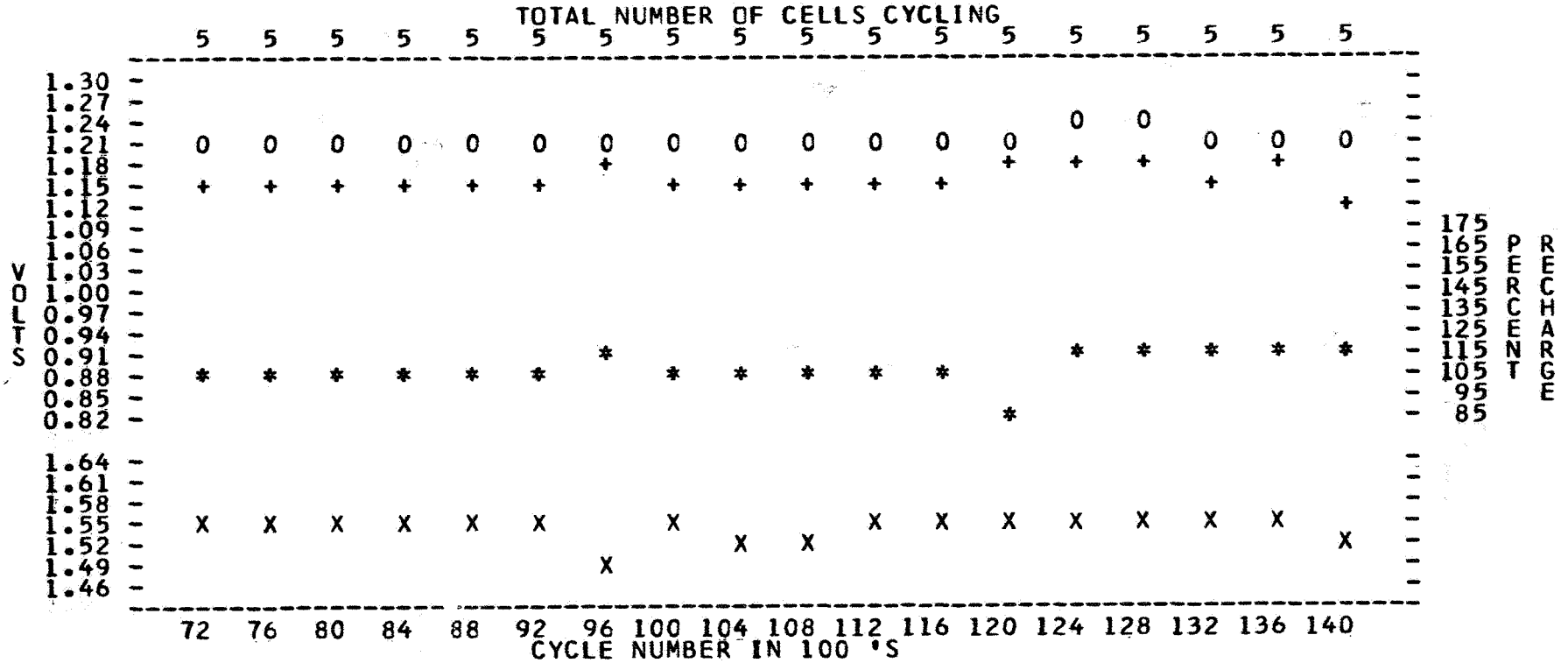
PACK NUMBER 032B
TYPE OF CELLS GULTON 5.60 AH
TEST TEMPERATURE -20 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 1.61 AMP.

STATUS CELLS CYCLING 4
CYCLES COMPLETED 16473

CAPACITY CHECK CYCLES
2696, 4031, 6288, 8423, 9766
11143,12549,14050,15459,

FIGURE 18(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



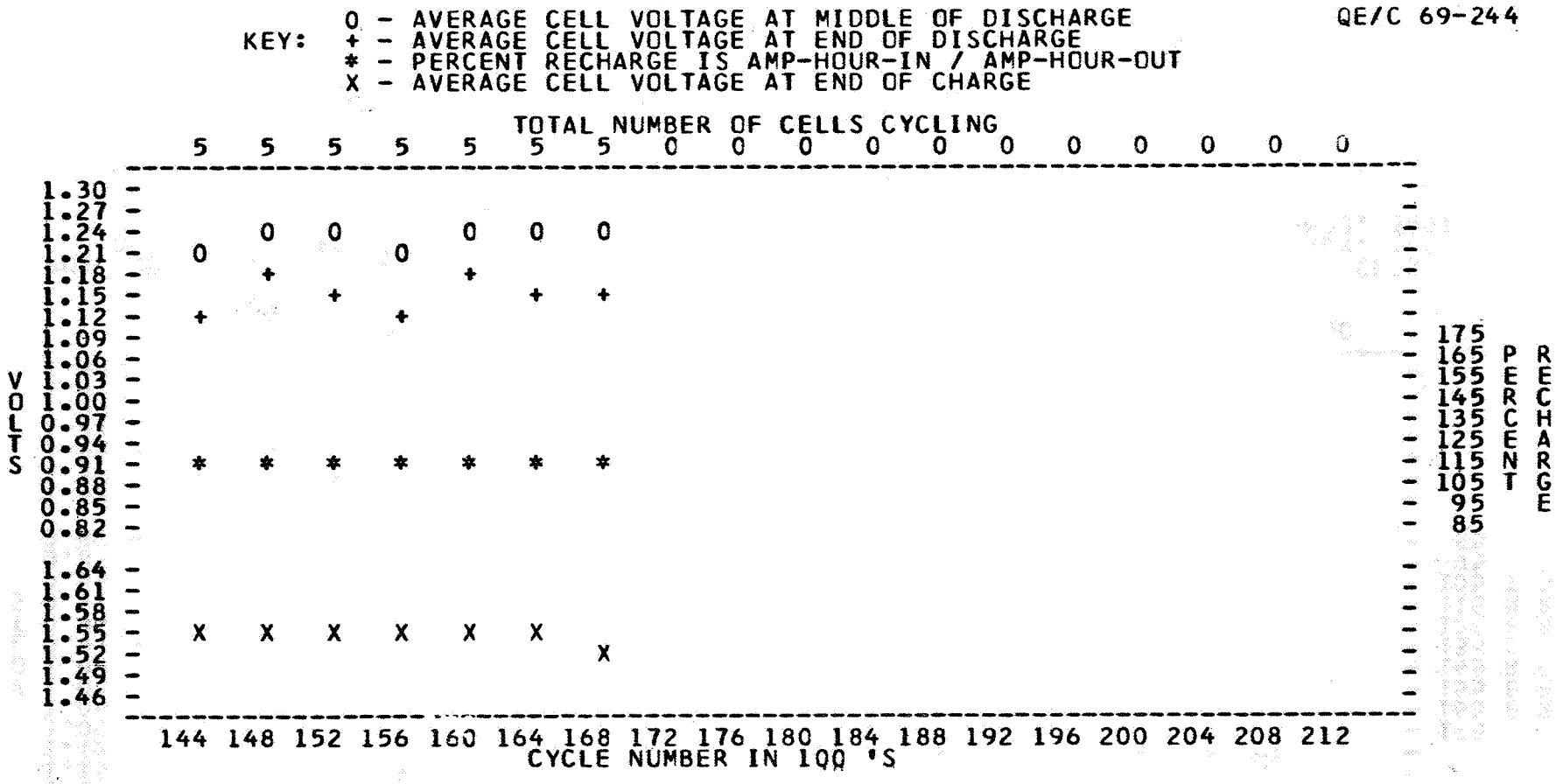
POS. NO. CYCLE FAILED

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.

STATUS CELLS CYCLING 5
CYCLES COMPLETED 16745

CAPACITY CHECK CYCLES
1781, 3170, 4819, 6533, 7939
9235,10531,11825,13230,14525
15921,

FIGURE 18(C)



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.

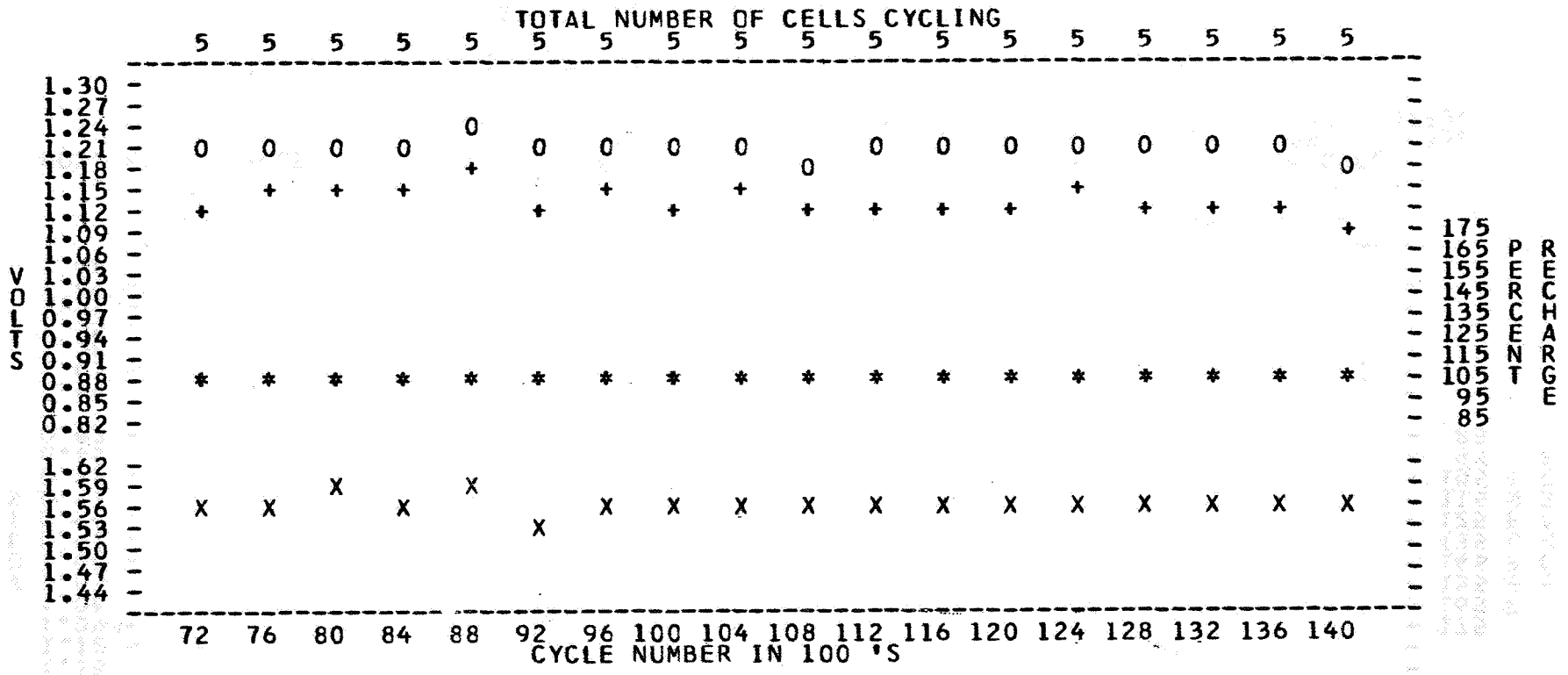
CAPACITY CHECK CYCLES
1781, 3170, 4819, 6533, 7939
9235,10531,11825,13230,14525
15921,

STATUS CELLS CYCLING 5
CYCLES COMPLETED 16745

FIGURE 18(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 16325

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.

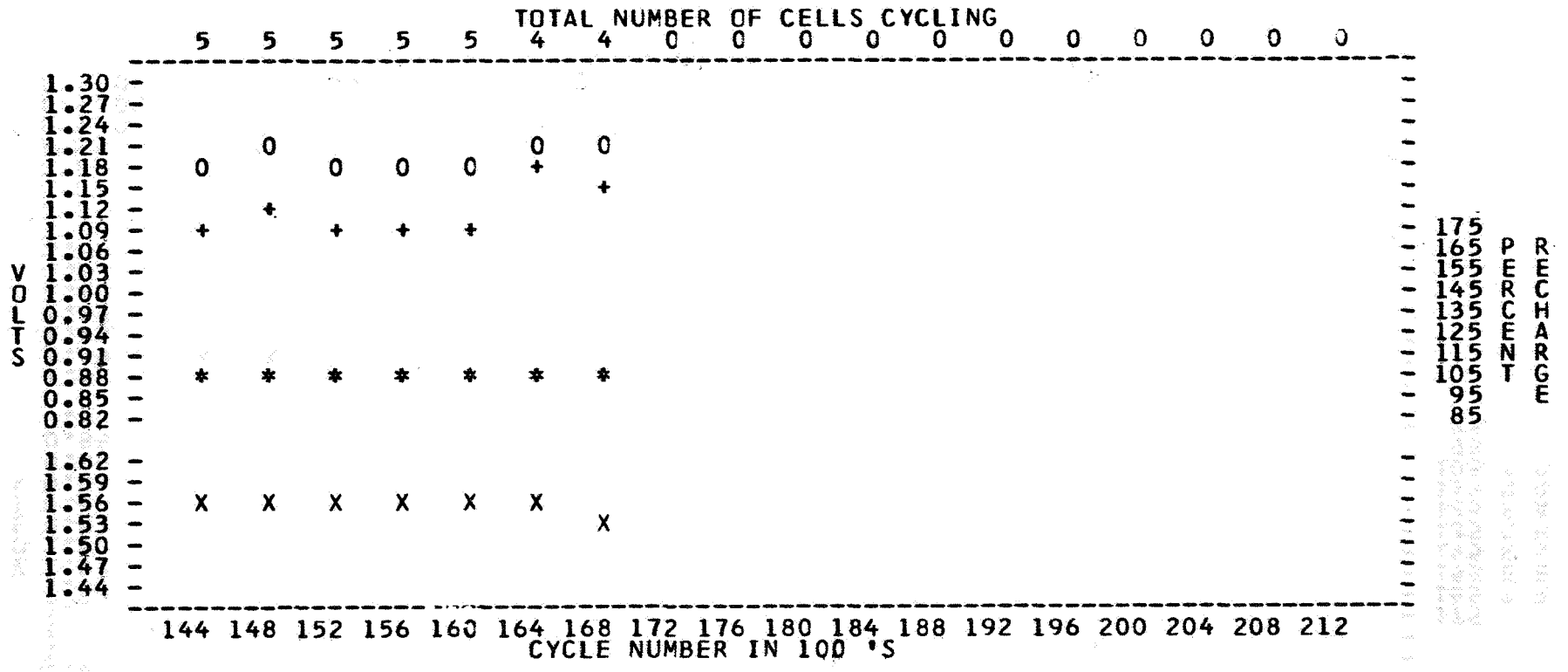
STATUS CELLS CYCLING 4
CYCLES COMPLETED 16831

CAPACITY CHECK CYCLES
1885, 3228, 4909, 6642, 8048
9341,10780,12073,13451,14856
16172,

FIGURE 18(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 69-244



POS. NO.	CYCLE FAILED		
05	16325		

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.

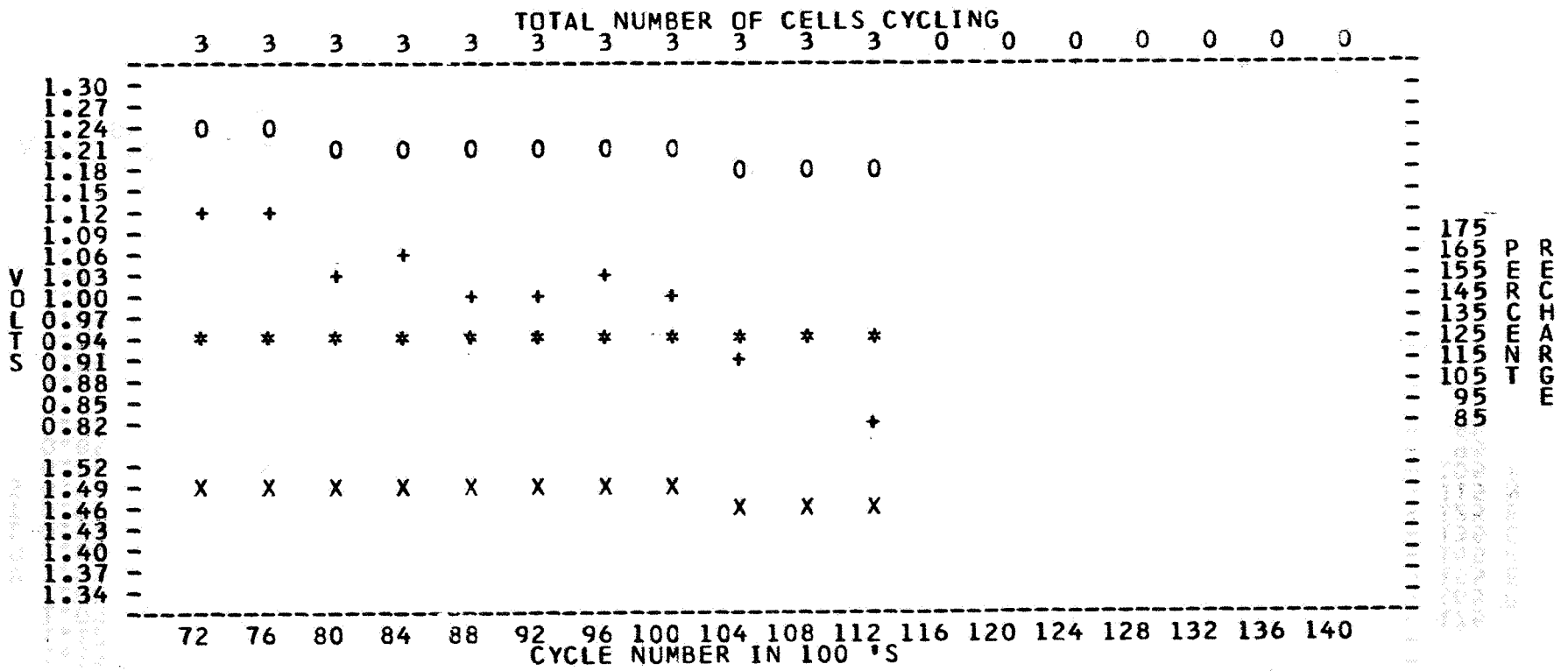
STATUS CELLS CYCLING 4
CYCLES COMPLETED 16831

CAPACITY CHECK CYCLES
1885, 3228, 4909, 6642, 8048
9341,10780,12073,13451,14856
16172,

FIGURE 18(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
02	2025
05	6330
04	11158

PACK NUMBER 076B
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.

STATUS CELLS CYCLING 3
CYCLES COMPLETED 11158

CAPACITY CHECK CYCLES
1714, 2912, 4291, 6327, 7539
8832,10242,

FIGURE 18(E)

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 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 the cells described in Section I, Paragraph I.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. Two cell failures on cycle 545 failed the pack.

(a) All cell voltages became quite low at the end of discharge with the original 150 percent of recharge. Increase of the recharge 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; then 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 voltages 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 first two failures were 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 precycling and capacity check cycles are as follows:

Precycling		6.60
88 Days	Disch #1	2.88
	Disch #2	3.55
176 Days	Disch #1	3.15
	Disch #2	4.40
264 Days	Disch #1	2.90
	Disch #2	4.25
352 Days	Disch #1	2.95
	Disch #2	4.05
440 Days	Disch #1	2.85
	Disch #2	3.50 F

F - Failed

6. Gulton 6.0 ah (Improved), Three 5-cell Packs, 1.5-hour Orbit 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 like the cells described in Section I, Paragraph I.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 19.) Cycling was started in February 1965. Pack 13B completed 21,529 cycles to date with no cell failures. Pack 18B failed at cycle 7577 and Pack 38B at cycle 5766.

(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 voltages were lower and more variable.

(b) Pack 18B: The three failed cells showed separator deterioration, blisters on the positive plates and migration of negative plate material. One cell had a ceramic short.

(c) Pack 38B: The three failed cells showed separator deterioration, blisters on the positive plates, migration of negative plate material and burned positive plate tabs. Two of the cells had a ceramic short, and one cell a leak at the terminal. In one cell the separator deterioration was so severe that the positive and negative plates shorted together resulting in high internal pressure.

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

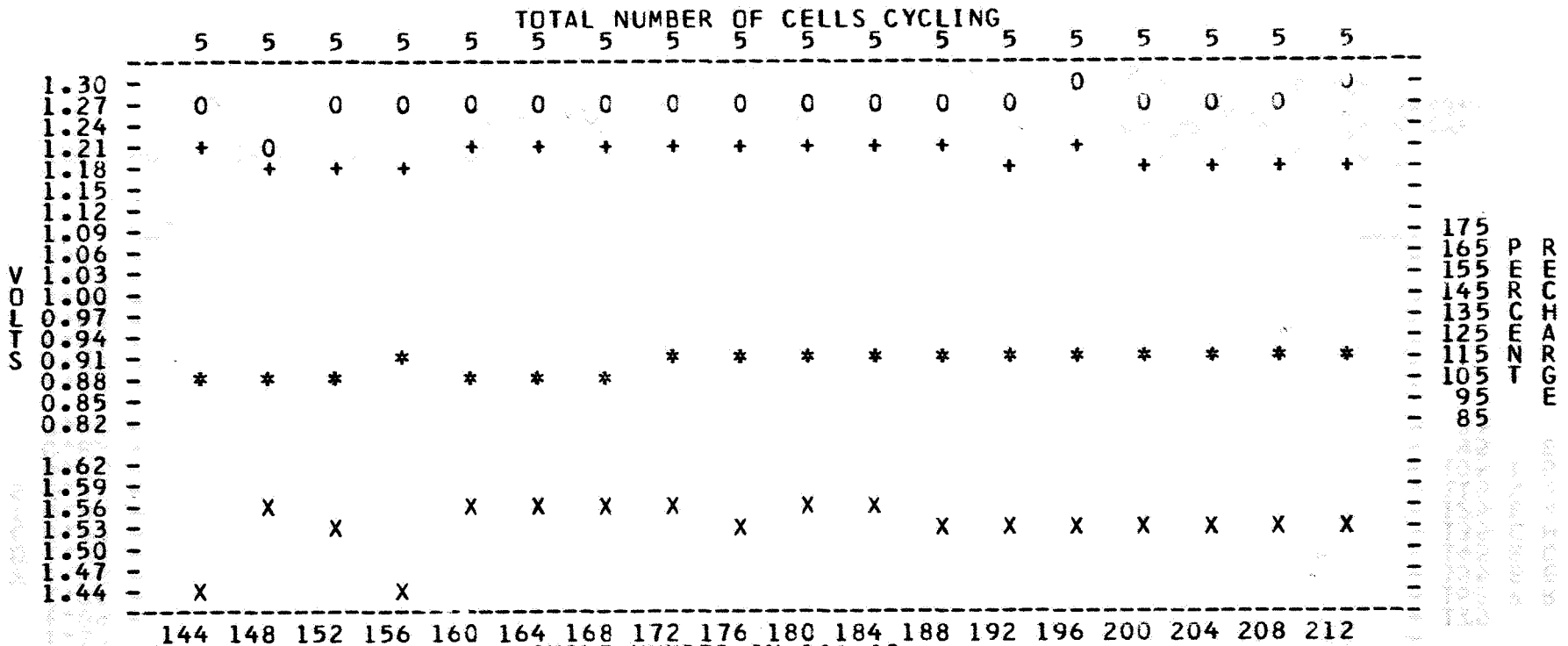
PRECYCLING AND CAPACITY CHECKS

Orbit Period			1.5-hour	
Temperature		0°	25°	40°
Depth of Discharge		25%	40%	25%
Pack Number		13B	18B	38B
Precycling 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
			F	F
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		
968 Days	Disch #1	4.15		
	Disch #2	5.00		
1056 Days	Disch #1	4.05		
	Disch #2	4.80		
1144 Days	Disch #1	2.20		
	Disch #2	4.05		

* Missed Capacity Check
F - Failed

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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 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.

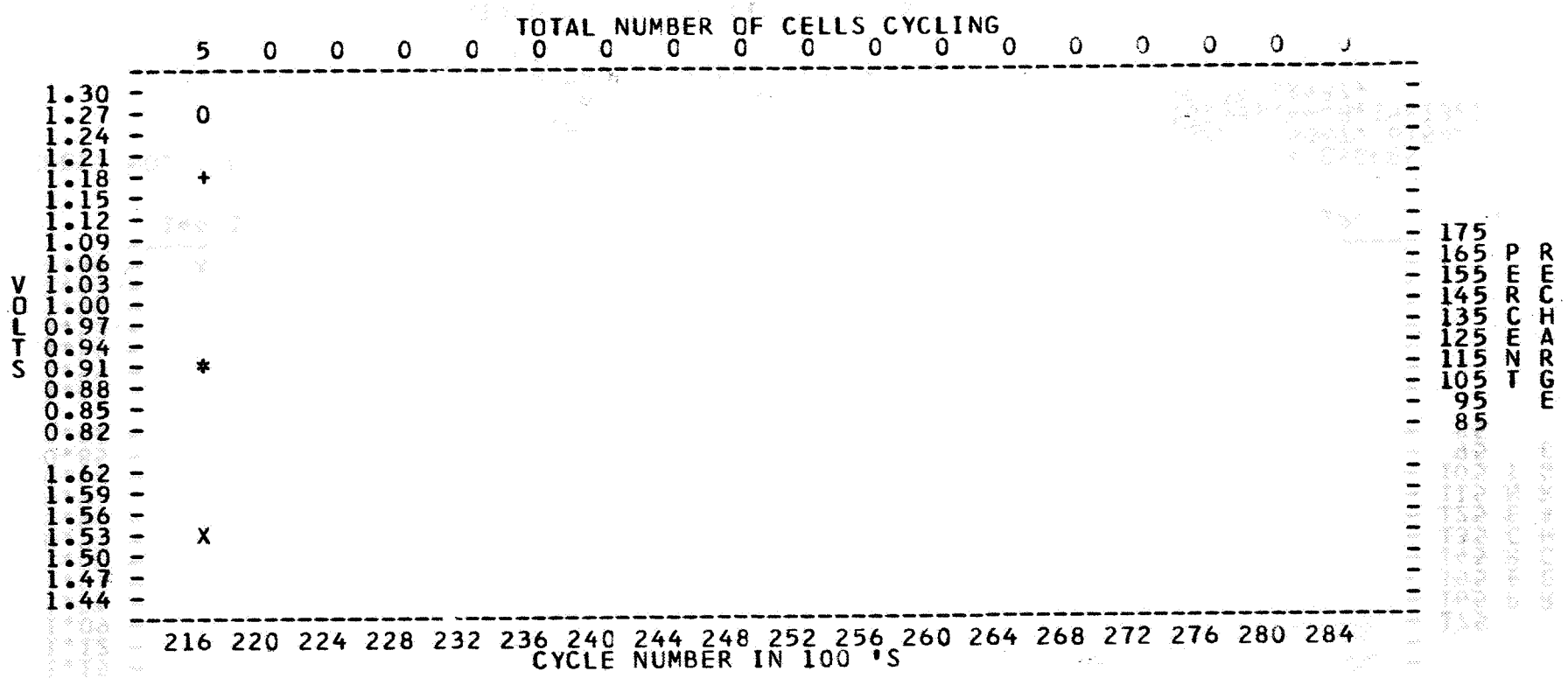
STATUS CELLS CYCLING 5
CYCLES COMPLETED 21529

CAPACITY CHECK CYCLES
1381, 3080, 4367, 6159, 7075
8048,13253,14408,15813,17138
18624,20034,21487,

FIGURE 19

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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 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.

STATUS CELLS CYCLING 5
CYCLES COMPLETED 21529

CAPACITY CHECK CYCLES
1381, 3080, 4367, 6159, 7075
8048,13253,14408,15813,17138
18624,20034,21487,

FIGURE 19 (CONTD)

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

a. Cell 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 cells as described in Section I, Paragraph I.A.3.a.

b. Test Parameters:

(1) Initial Test Parameters (at another 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 20.) Cycling was started at NAD Crane in June 1967. This pack has completed 8570 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.

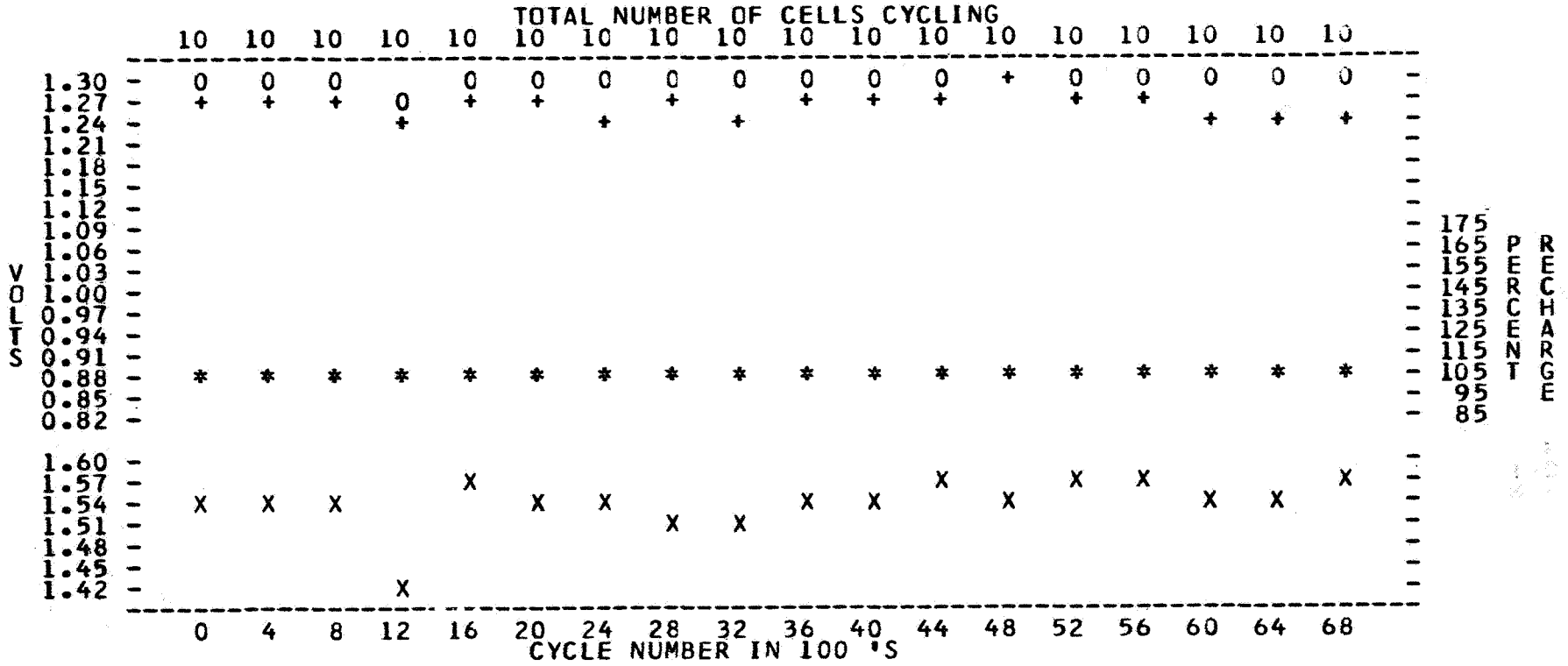
(2) Capacity checks: The ampere-hour capacities on the precycling and capacity check cycles are as follows:

PRECYCLING AND CAPACITY CHECKS

Orbit Period		1.5-hour
Temperature		0°
Depth of Discharge		10%
Pack Number		61B
Precycling Capacity		5.30
88 Days	Disch #1	5.20
	Disch #2	5.40
176 Days	Disch #1	5.10
	Disch #2	5.50
264 Days	Disch #1	5.00
	Disch #2	5.45
352 Days	Disch #1	4.60
	Disch #2	4.95
440 Days	Disch #1	4.25
	Disch #2	4.70
528 Days	Disch #1	1.85
	Disch #2	3.95

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 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.

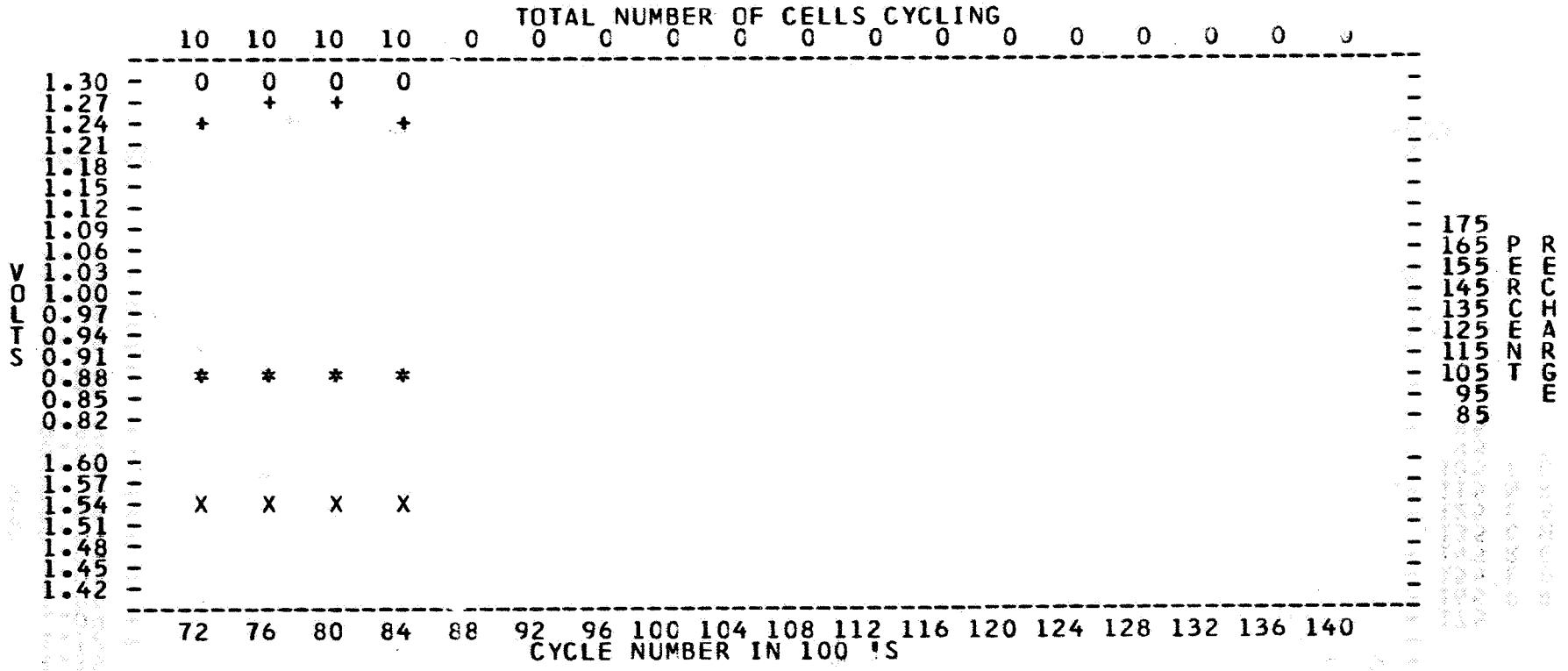
CAPACITY CHECK CYCLES
1444, 2708, 4113, 5603, 7011
8416,

STATUS CELLS CYCLING 10
CYCLES COMPLETED 8570

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 20

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 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, 4113, 5603, 7011
8416,

STATUS CELLS CYCLING 10
CYCLES COMPLETED 8570

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 20 (CONTD)

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 21(A) and 21(B).) Cycling was started in January 1966. Packs 16B and 101B have completed 20,572 and 21,821 cycles to date, with one cell failure on Pack 101B. Packs 27B and 96B failed on cycles 14,250 and 5152 respectively. Packs 78A and 90B failed on cycles 11,081 and 5124 respectively.

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

(b) Pack 101B: The one failed cell showed separator deterioration, migration of negative plate material, and blisters on the positive plates. The cell had some leakage as evidenced by a weight loss of 9.6 grams and had high pressure.

(c) Pack 27B: The three failed cells showed separator deterioration and migration of negative plate material.

One of the cells had blisters on the positive plates and two had high pressure.

(d) Pack 96B: The three failed cells showed separator deterioration, two of which showed migration of negative plate material. One cell had extraneous active material between one plate and adjacent separator. Two cells, which showed high pressure as evidenced by their bulged cases, also developed leaks as evidenced by a deposit on one cell and loss in weight of 3.3 grams of the other cell.

(e) Pack 78A: The three failed cells showed separator deterioration and migration of negative plate material. The positive plates of two cells were blistered. Two cells had high pressure; the case of one was bulged, whereas pressure was released when the other cell was opened.

(f) Pack 90B: The three failed cells showed separator deterioration, migration of negative plate material, and blisters on the positive plates. One of the cells had high pressure as evidenced by bulging of the case.

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

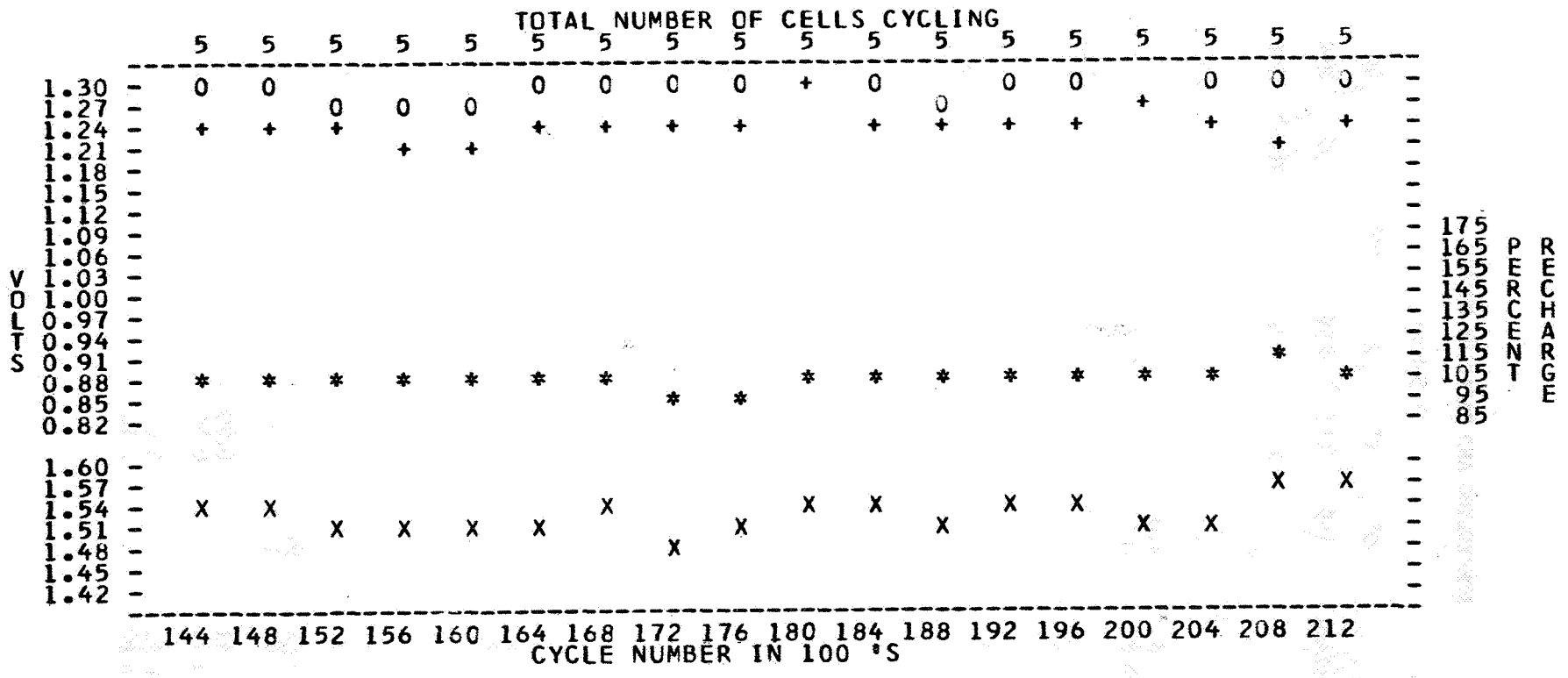
PRECYCLING AND CAPACITY CHECKS

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
Precycling 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 F	3.30	3.70 F
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 F	
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 F			
880 Days	Disch #1	12.00	8.20				
	Disch #2	12.30	8.88				
968 Days	Disch #1	11.00	8.80				
	Disch #2	11.80	9.00				
1056 Days	Disch #1	10.80	7.50				
	Disch #2	11.60	8.40				
1144 Days	Disch #1	9.70	7.60				
	Disch #2	11.50	8.80				
1232 Days	Disch #1		6.70				
	Disch #2		8.40				
1320 Days	Disch #1		6.60				
	Disch #2		8.10				

F - Failed

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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 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.

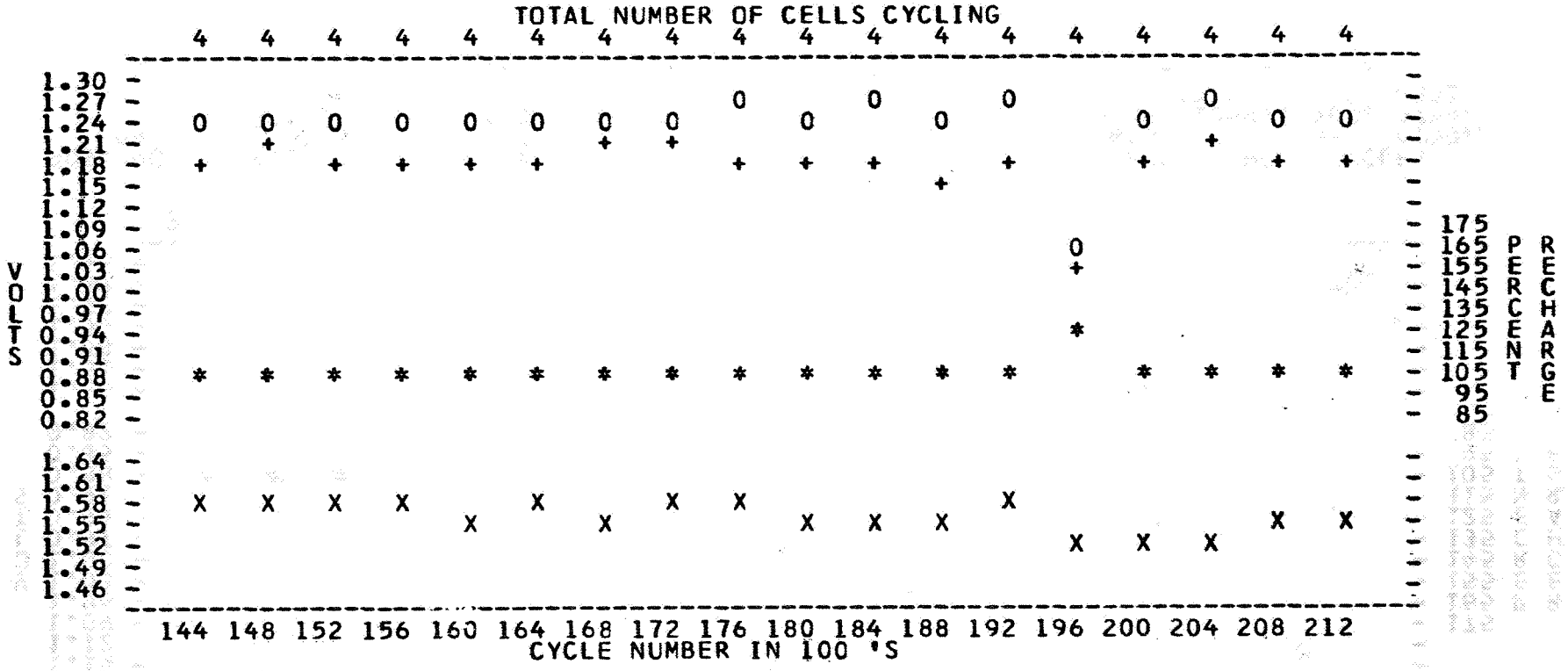
STATUS CELLS CYCLING 5
CYCLES COMPLETED 21529

CAPACITY CHECK CYCLES
1407, 2867, 4078, 5628, 7253
8572,10557,11964,12138,13401
14955,16326,17736,19186,20569
0, 0, 0, 0, 0

FIGURE 21(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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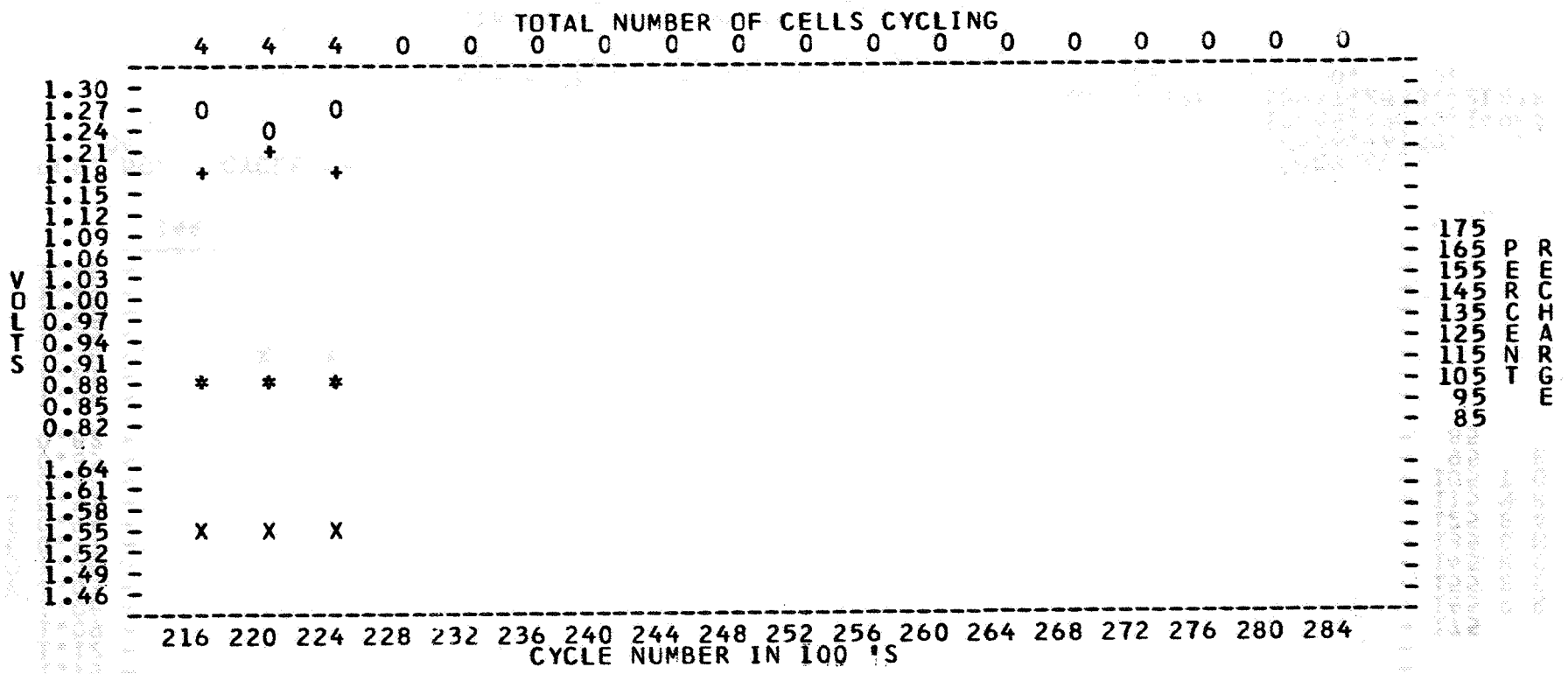
POS. NO.	CYCLE FAILED	PACK NUMBER	101B	CAPACITY CHECK CYCLES
04	5586	TYPE OF CELLS	GULTON 12.00 AH	1416, 3371, 4526, 6159, 7727
		TEST TEMPERATURE	00 DEGREES C.	9315,11059,12465,13759,14942
		ORBIT PERIOD	01.5 HOURS	16429,17850,18937,20331,21818
		DEPTH OF DISCHARGE	25 PERCENT	0, 0, 0, 0, 0
		SPECIFIED CHARGE RATE	3.45 AMP.	

STATUS CELLS CYCLING 4
CYCLES COMPLETED 22308

FIGURE 21(B)

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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. 04 CYCLE FAILED 5586

PACK NUMBER 101B
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 3.45 AMP.

STATUS CELLS CYCLING 4
CYCLES COMPLETED 22308

CAPACITY CHECK CYCLES
1416, 3371, 4526, 6159, 7727
9315,11059,12465,13759,14942
16429,17850,18937,20331,21818
0, 0, 0, 0, 0

FIGURE 21(B) (CONTD)

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 failed cell and slight migration of material from the negative plates was evident in the second failed cell. The positive plates of the third failed cell showed large blisters, and separators impregnated with negative plate material.

(b) Pack 123A completed 1873 cycles when the first cell failure occurred. It had low voltage during the discharge and the recharge. Two additional cells shorted out while the pack was off cycling to remove the first failed cell. The separators of all three cells had deteriorated, resulting in shorts between the plates in two of these cells, creating hot spots on all plates thus shorted. The outside negative plates of two cells were stuck to the case. The 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 precycling and capacity check cycles are as follows:

(a) Pack 95A:

Precycling	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	Failed

(b) The precycling 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 manufactured to the NIMBUS specifications.

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 22(A) through 22(C).) Cycling was started in May 1965. Packs 103A, 107A and 106A have completed 20,463, 19,856 and 20,470 cycles respectively to date with no cell failures. Packs 104B, 113A and 114A failed on cycles 13,149, 4998 and 8273 respectively.

(a) Pack 104B: The three failed cells showed separator deterioration, migration of negative plate material, and leakage as evidenced by carbonate deposit around the terminal of two cells and a weight loss of 1.8 grams on one cell. Two of the cells developed high pressure as evidenced by release of pressure upon opening, one of which had been shorted by the negative tab piercing through the separator to the negative plate.

(b) Pack 113A: This pack was destroyed by thermal runaway caused by shorting of the positive tab to the negative plate in four of the five cells. The separators of the five cells were deteriorated. All cells had developed high pressure as evidenced by pressure release upon opening.

(c) Pack 114A: The three failed cells showed separator deterioration which resulted in shorting between the plates, and migration of negative plate material. The positive plate of one cell was blistered. The three cells had high internal pressure as evidenced by release of pressure upon opening.

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

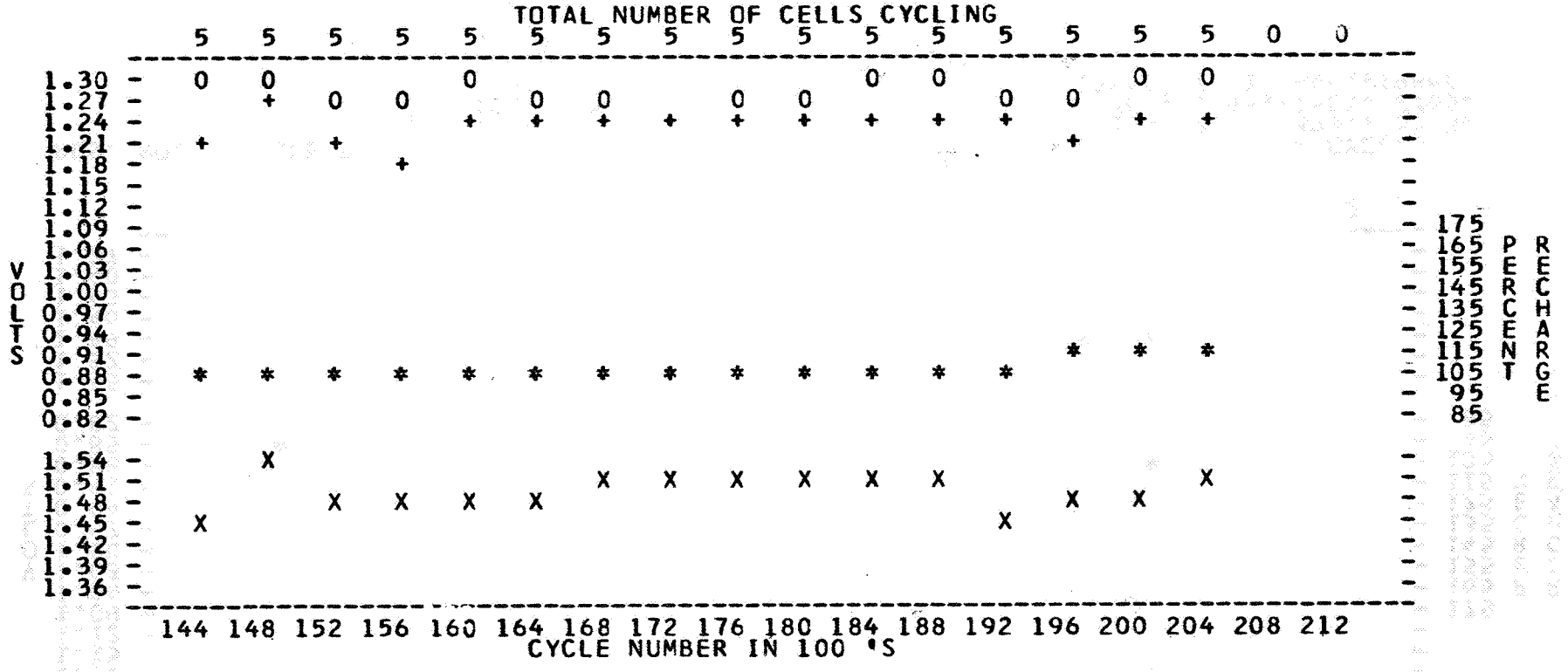
PRECYCLING AND CAPACITY CHECKS

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
Precycling 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 F	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 F
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 F		
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			
968 Days	Disch #1	2.67	3.75	1.46			
	Disch #2	5.17	4.46	2.92			
1056 Days	Disch #1	4.37	3.12	1.58			
	Disch #2	4.87	4.37	3.00			
1144 Days	Disch #1	3.87	2.92	1.25			
	Disch #2	5.08	4.21	2.58			
1232 Days	Disch #1	3.67	2.87	1.33			
	Disch #2	4.79	4.29	2.92			

F - 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.

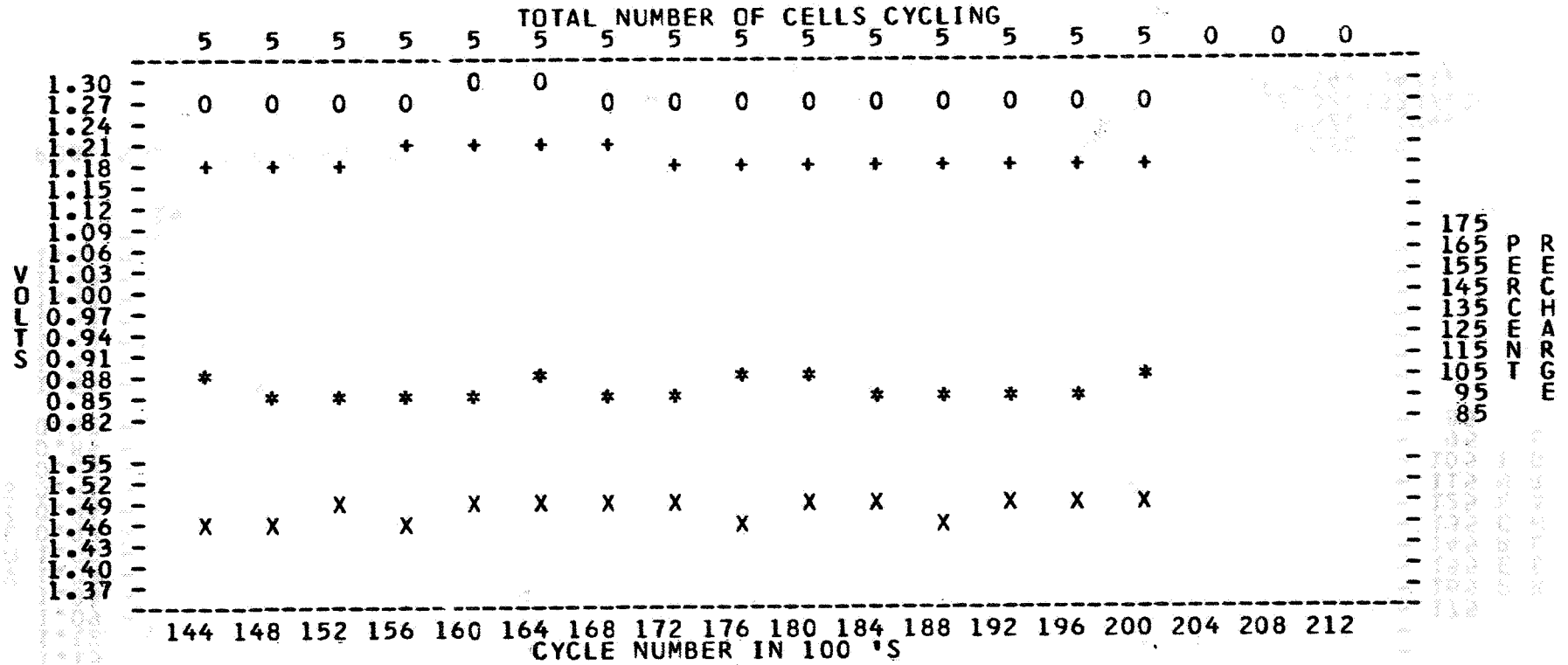
STATUS CELLS CYCLING 5
CYCLES COMPLETED 20463

CAPACITY CHECK CYCLES
1846, 2987, 4582, 6194, 7543
9419,10794,12232,13387,14795
16121,17609,19014,20421,

FIGURE 22(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 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.

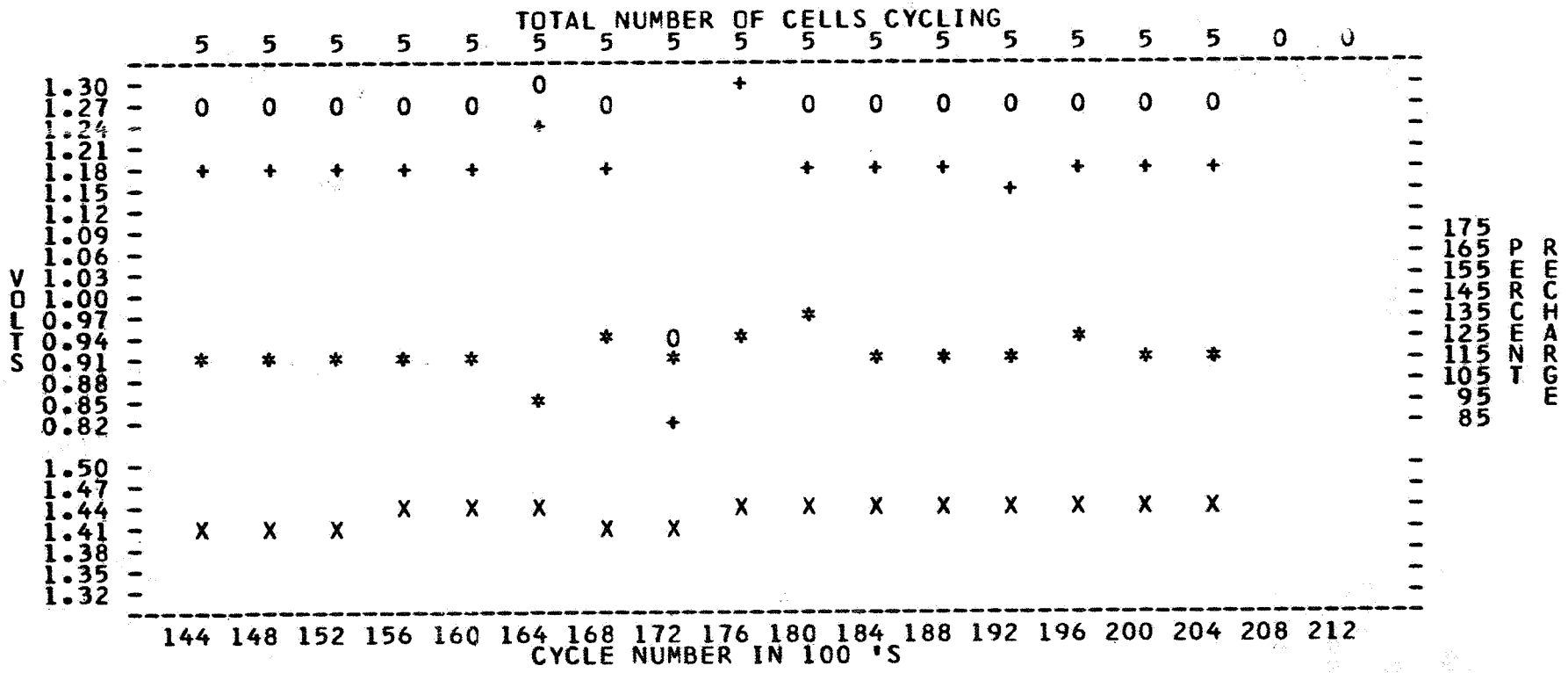
STATUS CELLS CYCLING 5
CYCLES COMPLETED 19856

CAPACITY CHECK CYCLES
1195, 2336, 3931, 5543, 6892
8768,10143,11581,12765,14170
15546,17031,18441,19846,

FIGURE 22(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 69-244



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 20470

CAPACITY CHECK CYCLES
1529, 2356, 3958, 5588, 7027
8675,10373,11811,13074,14516
15775,17102,18509,19980,

FIGURE 22(C)

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 cells described in Section I, Paragraph I.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 was considered as failed on cycle 349.

(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 insufficient charge acceptance. 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 (including the one returned cell) 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 precycling and capacity check cycles are as follows:

Precycling at 25° C	100 Days Discharge at 25° C #1	#2	231 Days Discharge at 40° C #1	#2	339 Days Discharge at 40° C #1	#2	
13.0	6.55	7.60	5.20	6.50	5.00	5.00	F

F - Failed

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	Percent 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 23(A) and 23(B).) Cycling was started in July 1965. Packs 43B and 31B have completed 19,058 and 18,735 cycles respectively with only one cell failure on Pack 31B. Packs 3B, 2B, 26B and 37B failed on cycles 11,726, 5399, 6289 and 5625 respectively.

(a) Pack 31B: The one failed cell showed migration of negative plate material which was greater under the areas of excessive scoring, a weak weld between the positive tab and plate, and leakage as evidenced by a deposit around the terminal.

(b) Pack 3B: The three failed cells showed separator deterioration and migration of negative plate material. The plates of each of two cells were shorted; one by a grid wire

through the separator, and one by the positive tab through the separator. One cell had a weak weld between the positive tab and plate, and had some leakage at the seam of the fill tube. One cell had high pressure as evidenced by pressure release upon opening of the cell.

(c) Pack 2B: The three failed cells showed separator deterioration and migration of negative material, both conditions being greater in the areas under the excessive scoring on the three cells. The weld between the positive tab and the plate in each of the three cells was weak.

(d) Pack 26B: The three failed cells showed separator deterioration and migration of negative material, both conditions being greater in the area under the excessive scoring on the three cells. The weld between the positive tab and plate of two cells was weak. One cell showed leakage at the welded seam, and one cell had some loosened positive active material.

(e) Pack 37B: The three failed cells showed separator deterioration and migration of negative material, both conditions being greater in the areas under the excessive scoring on the three cells. The weld of the positive tab to the plate in two of the cells was weak.

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

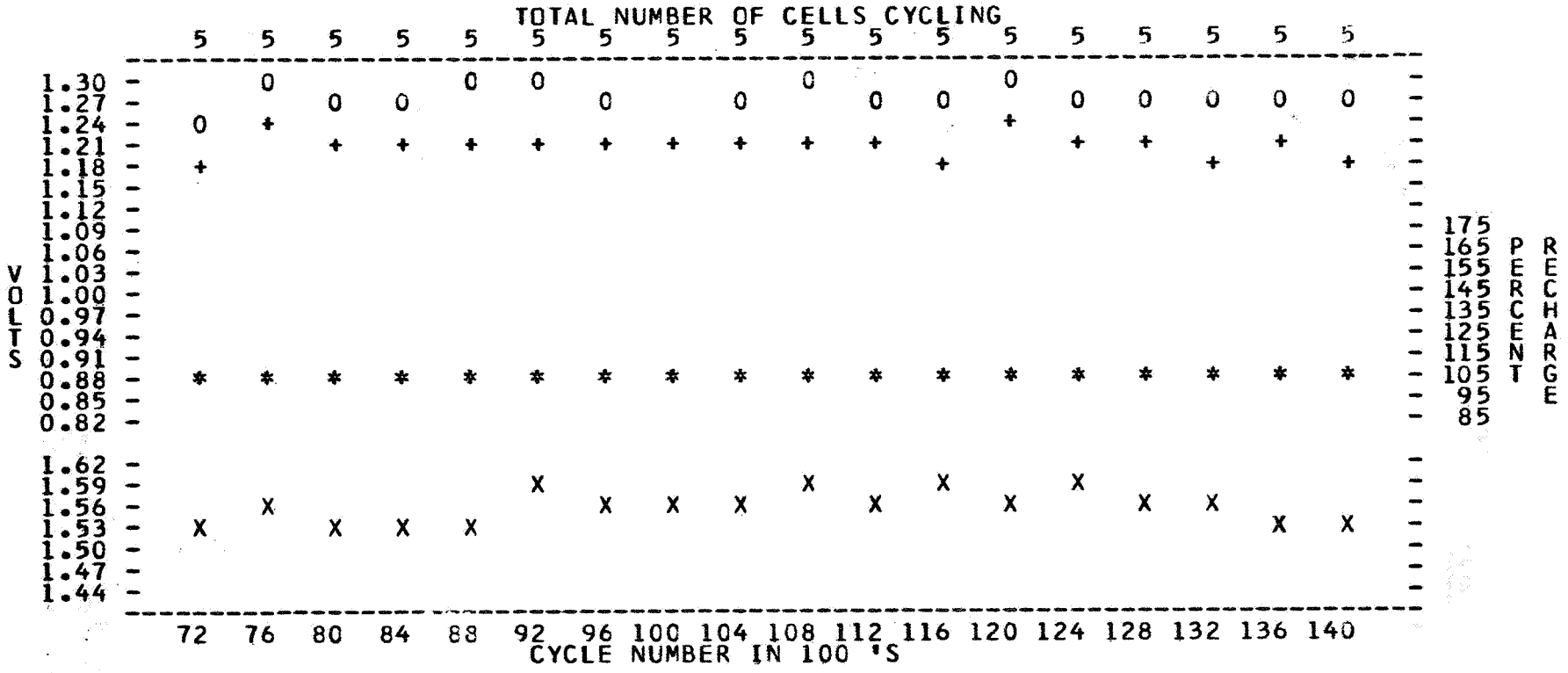
PRECYCLING AND CAPACITY CHECKS

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
Precycling 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
					F		F
352 Days	Disch #1	3.40	2.37	1.43		0.42	
	Disch #2	2.63	2.67	1.45		0.47	
						F	
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			
				F			
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				
1056 Days	Disch #1	2.20	1.97				
	Disch #2	2.50	2.48				
1144 Days	Disch #1	2.22	2.00				
	Disch #2	2.32	2.27				
1232 Days	Disch #1	1.92	1.85				
	Disch #2	2.15	2.20				
1320 Days	Disch #1	1.92	1.95				
	Disch #2	2.10	2.10				

F - 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

QE/C 69-244



POS. NO. CYCLE FAILED

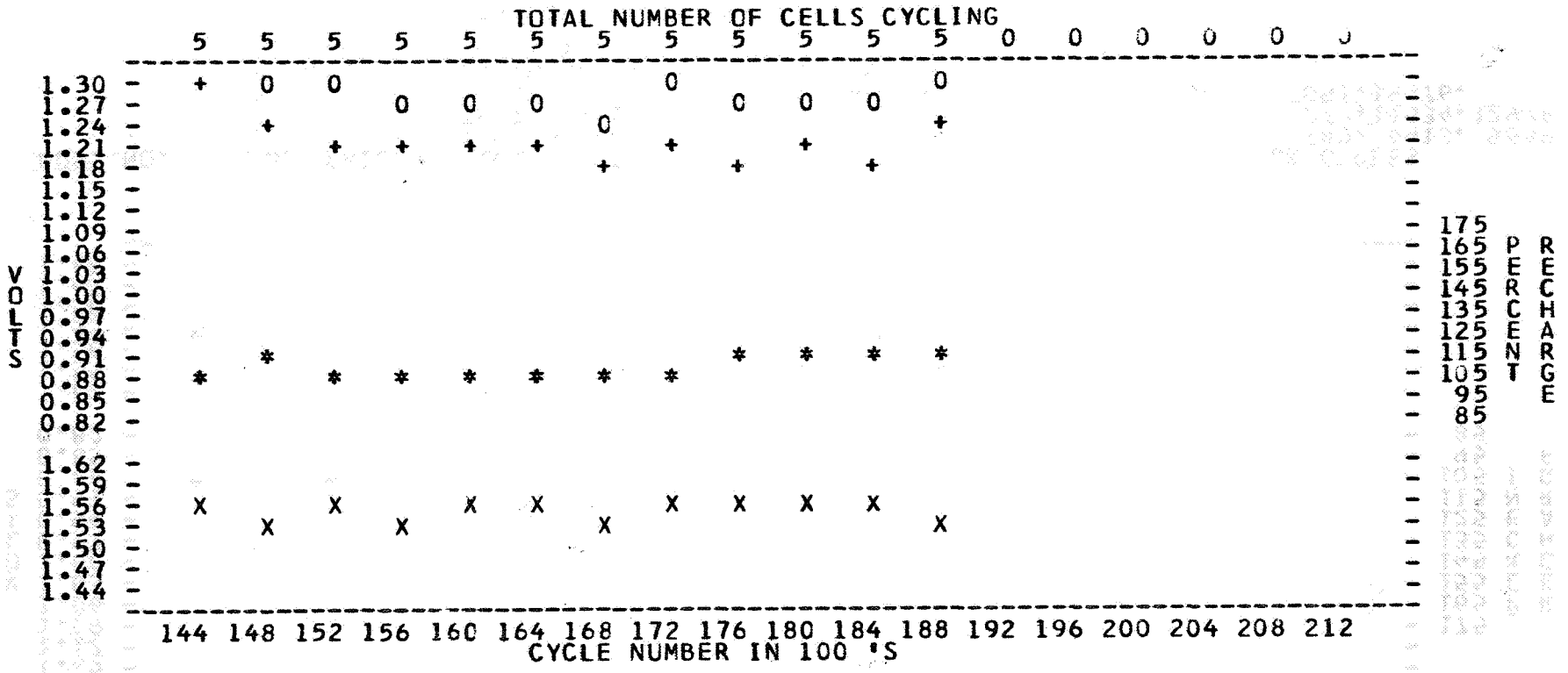
PACK NUMBER 0438
TYPE OF CELLS SONOTONE 3.00 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 15 PERCENT
SPECIFIED CHARGE RATE 0.52 AMP.

STATUS CELLS CYCLING 5
CYCLES COMPLETED 19058

CAPACITY CHECK CYCLES
1274, 2430, 2780, 4413, 5689
7311, 8864,10270,11534,12974
14268,15641,17051,18376,

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



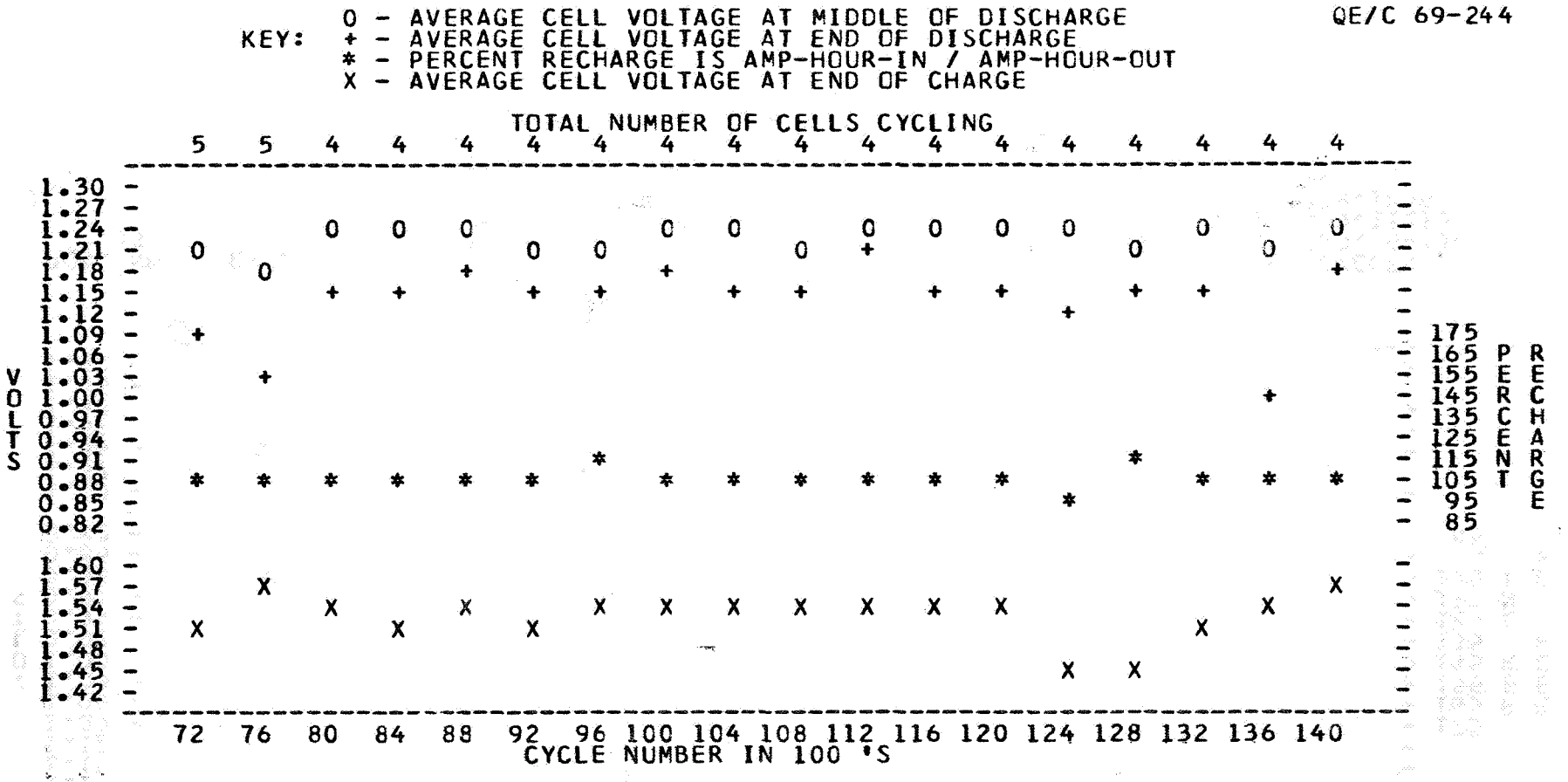
POS. NO. CYCLE FAILED

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 19058

CAPACITY CHECK CYCLES
1274, 2430, 2780, 4413, 5689
7311, 8864,10270,11534,12974
14268,15641,17051,18376,

FIGURE 23(A) (CONTD)



POS. NO. 05

CYCLE FAILED 7636

PACK NUMBER 031B
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.

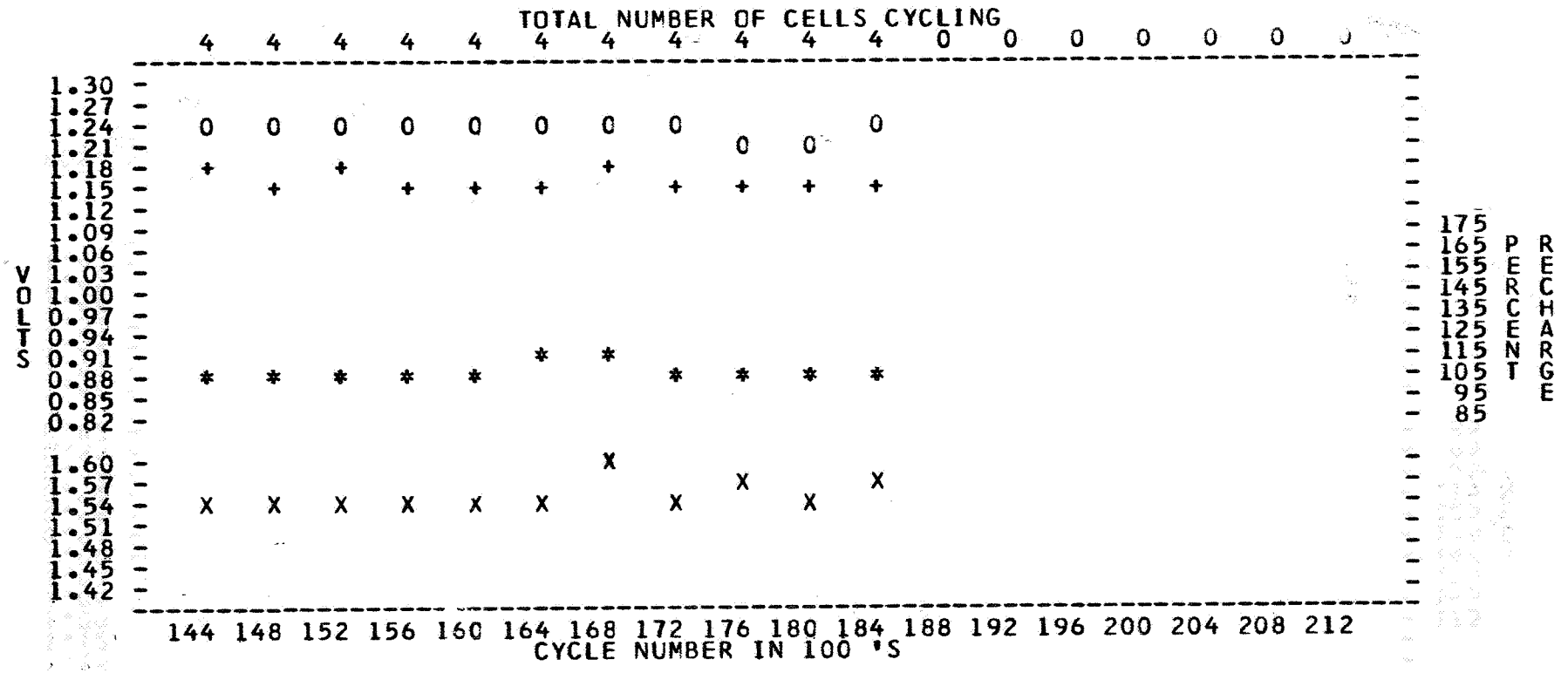
STATUS CELLS CYCLING 4
CYCLES COMPLETED 18735

CAPACITY CHECK CYCLES
1274, 2430, 2780, 4413, 5704
7326, 8543, 8949, 11210, 12563
13943, 15318, 16728, 18053,

FIGURE 23(B)

QE/C 69-244

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. 05

CYCLE FAILED 7636

PACK NUMBER 031B
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 18735

CAPACITY CHECK CYCLES
1274, 2430, 2780, 4413, 5704
7326, 8543, 8949, 11210, 12563
13943, 15318, 16728, 18053,

FIGURE 23(B) (CONTD)

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 another test facility):

(a) Test Temperature: -10° C.

(b) Depth of Discharge: 10%.

(c) Percent of Recharge: 110%.

(d) Charge 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 24.) This pack has completed 8538 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.

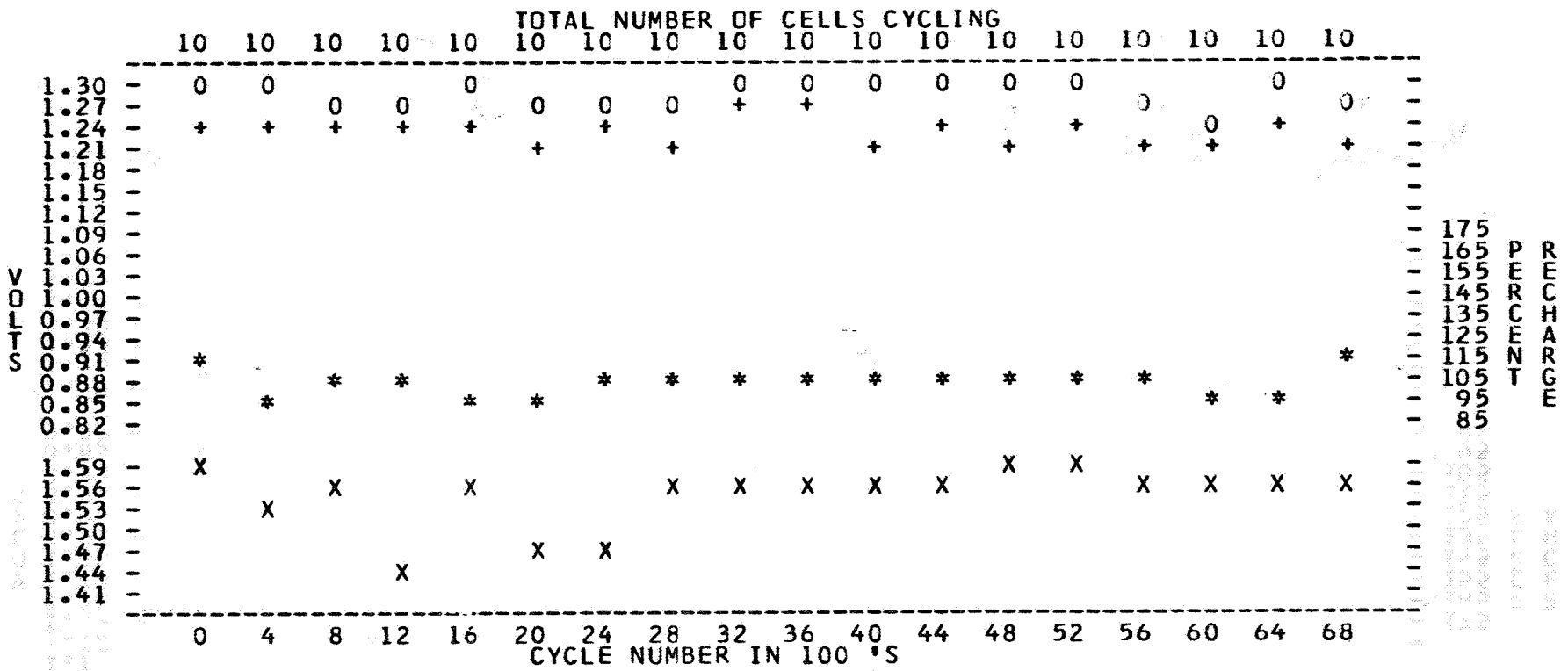
(2) Capacity checks: The ampere-hour capacities on the precycling and capacity check cycles are as follows:

PRECYCLING AND CAPACITY CHECKS

Orbit Period		1.5-hour
Temperature		-10°
Depth of Discharge		10%
Pack Number		15B
Precycling Capacity		3.18
88 Days	Disch #1	2.68
	Disch #2	3.09
176 Days	Disch #1	2.57
	Disch #2	2.86
264 Days	Disch #1	2.51
	Disch #2	2.95
352 Days	Disch #1	2.36
	Disch #2	2.77
440 Days	Disch #1	2.22
	Disch #2	2.60
528 Days	Disch #1	2.39
	Disch #2	2.71

QE/C 69-244

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 0158
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.

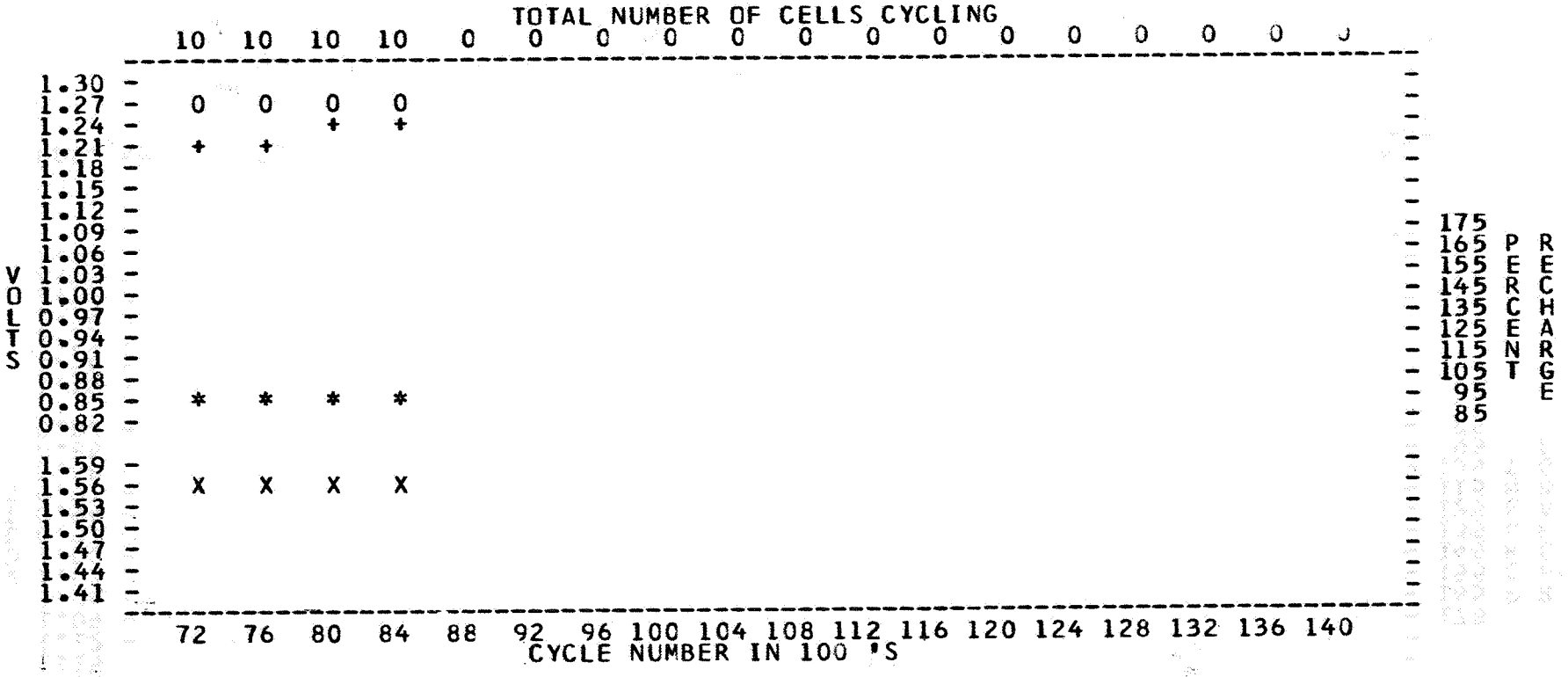
STATUS CELLS CYCLING 10
CYCLES COMPLETED 8538

CAPACITY CHECK CYCLES
2767, 4171, 5671, 7079, 8484
0,

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 24

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
2767, 4171, 5671, 7079, 8484
0,

STATUS CELLS CYCLING 10
CYCLES COMPLETED 8538

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 24 (CONTD)

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 25(A) and 25(B).) Cycling was started in September 1967. Packs 97C and 85C have completed 6936 and 6581 cycles respectively to date with no cell failures. Both packs have been cycling with very high end-of-discharge voltages indicating that the on-charge limits are sufficient to maintain the operation.

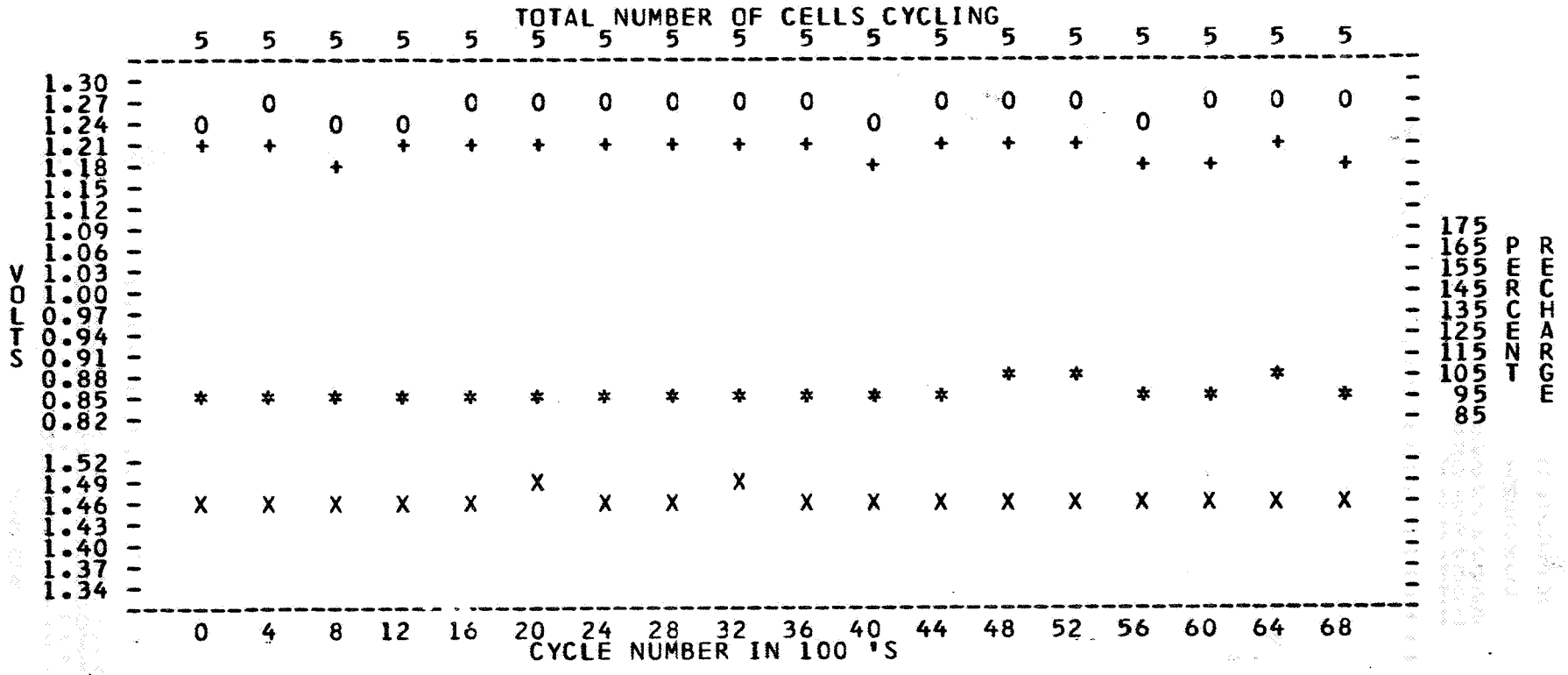
(2) Capacity checks: The ampere-hour capacities on the precycling and capacity check cycles are as follows:

PRECYCLING AND CAPACITY CHECKS

Orbit Period		1.5-hour	
Temperature		0°	25°
Depth of Discharge		25%	25%
Pack Number		97C	85C
Precycling Capacity		4.10	3.90
88 Days	Disch #1	3.37	2.87
	Disch #2	3.93	3.57
176 Days	Disch #1	3.10	2.33
	Disch #2	3.93	3.07
264 Days	Disch #1	3.03	1.93
	Disch #2	3.33	3.33
352 Days	Disch #1	2.83	1.67
	Disch #2	3.90	3.10
440 Days	Disch #1	1.73	1.67
	Disch #2	3.27	2.90

QE/C 69-244

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.

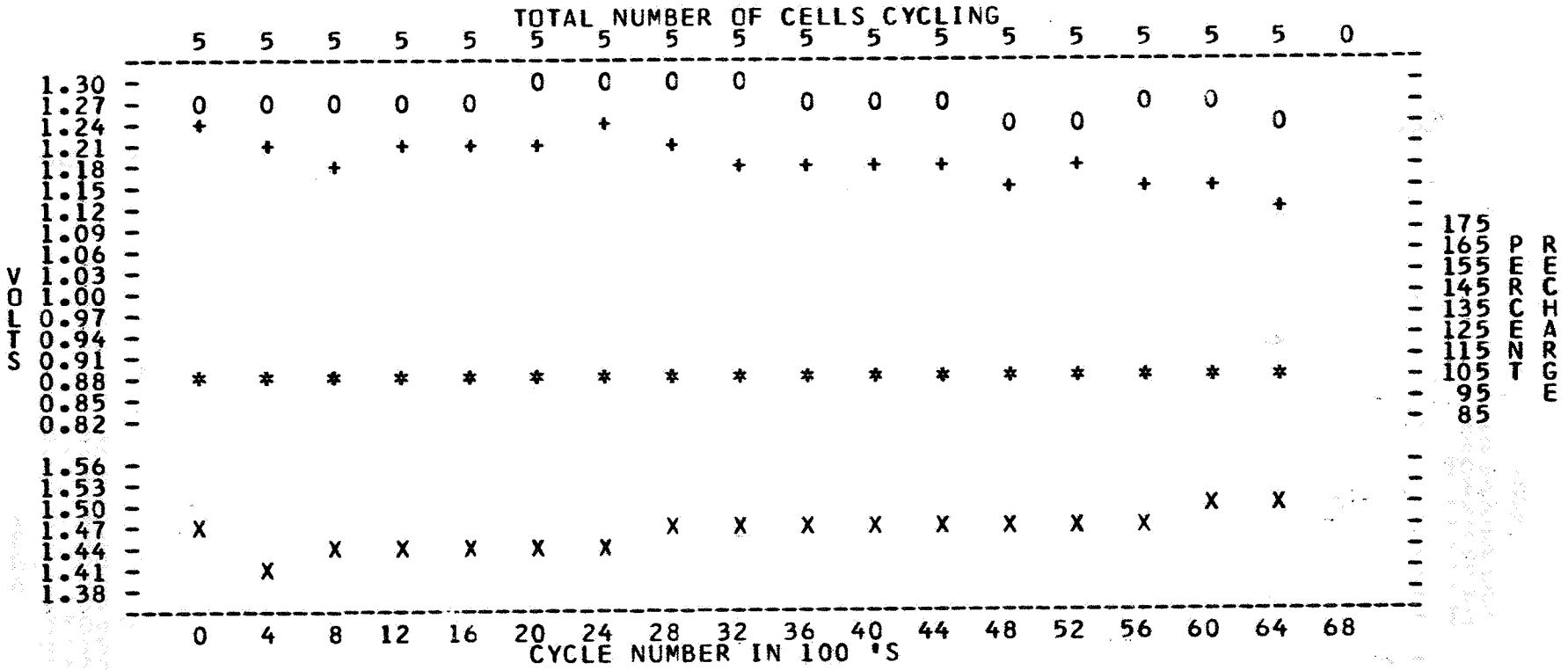
STATUS CELLS CYCLING 5
CYCLES COMPLETED 6936

CAPACITY CHECK CYCLES
1295, 2623, 4191, 5582,

FIGURE 25(A)

QE/C 69-244

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 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.

STATUS CELLS CYCLING 5
CYCLES COMPLETED 6581

CAPACITY CHECK CYCLES
1295, 2401, 3771, 5165,

FIGURE 25(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: 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 per cell, average. The percent of recharge was very close to 100 percent.

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

Precycling Capacity	2.52	
88-Day Discharge	*	
176-Day Discharge	0.85	
264-Day Discharge	0.87	
352-Day Discharge	0.67	Failed

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

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:

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

(2) Performance on cycling: Cycling was started in September 1965. Packs 57B, 21A and 45A failed on cycles 267, 98 and 61 respectively.

(a) Pack 57B: One cell failed on cycle 138, and two on cycle 267.

(b) Pack 21A: One cell failed on cycle 90, and two on cycle 98.

(c) Pack 45A: The pack failed on cycle 61 because of severe leakage.

(d) The three packs were returned to Goddard Space Flight Center for failure analysis.

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

PRECYCLING AND CAPACITY CHECKS

Orbit Period		24-hour	
Temperature	0°	25°	40°
Depth of Discharge	20%	20%	20%
Pack Number	57B	21A	45A
Precycling Capacity	3.67		6.00 F
100 Days	1.83	0.76 F	
200 Days	1.33 F		

F - 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) had been subjected to gama radiation (2×10^7 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:

(1) Performance on cycling: Cycling was started in October 1965. Cycling on Pack 9C was discontinued on cycle 34, and Pack 33B failed on cycle 720.

(a) Pack 9C: One cell failed on cycle 34. Since the separator material of the cells in this pack had been subjected to gama radiation, the pack was returned to Goddard Space Flight Center for analysis.

(b) Pack 33B: Two cells failed on cycle 720. While the pack was removed from cycling to disconnect the two failed cells, the three remaining cells failed. The pack was returned to Goddard Space Flight Center for failure analysis.

(2) Capacity checks: The ampere-hour capacities of Pack 33B on the capacity check cycles are as follows:

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

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: 25%.

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

c. Test Results: Cycling was started in October 1965. This pack failed on cycle 595 with its third cell failure, 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 cell voltages until the first cell failure at cycle 494. Also the internal pressure as read on the gages was very low.

d. Capacity Checks: The ampere-hour capacities on the 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 F

F - Failed

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 26(A) and 26(B).) Cycling was started in January 1967. Pack 113B completed 700 cycles to date with no cell failures. Packs 77B, 105B and 128B failed on cycles 661, 77 and 269 respectively. (Prior to start of this test, Packs 77B and 105B were cycled at Goddard Space Flight Center for about 1 year. Most of that "cycling" was continuous float.)

(a) Pack 77B: This pack failed on cycle 661 with its third cell failure. The first two cell failures occurred on cycles 500 and 509. Failure of these three cells was due to silver migration and separator deterioration.

(b) Pack 105B: This pack failed on cycle 77 when two of three cell failures occurred. The first cell failure was on cycle 69. Failure of these three cells was due to silver migration and separator deterioration.

(c) Pack 128B: This pack failed on cycle 269 when two of the three cell failures occurred. The first cell failure occurred on cycle 123. Failure of these three cells was due to silver migration and separator deterioration.

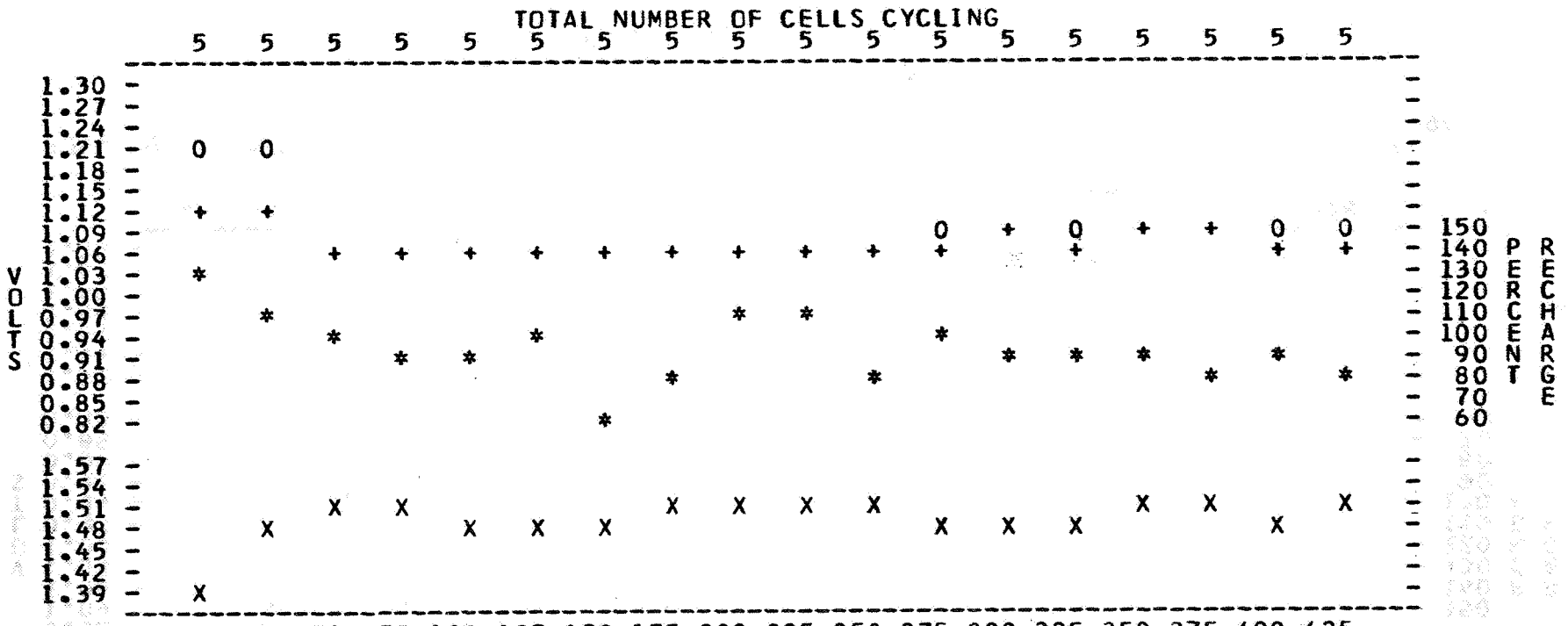
(2) Capacity checks: The ampere-hour capacities on the precycling and capacity check cycles are as follows:

Orbit Period	24-hour			
Temperature	0°	25°	25°	40°
Depth of Discharge	20%	20%	20%	20%
Pack Number	113B	77B	105B	128B
Precycling Capacity	4.08	5.02	4.95 F	6.47
100 Days	5.27	4.92		5.53
200 Days	4.08	4.77		1.25 F
300 Days	4.67	4.67		
400 Days	5.55	4.67		
500 Days	4.03	1.25		
600 Days	5.06	2.35 F		

F - 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

QE/C 69-244



POS. NO. CYCLE FAILED

PACK NUMBER 113B
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.

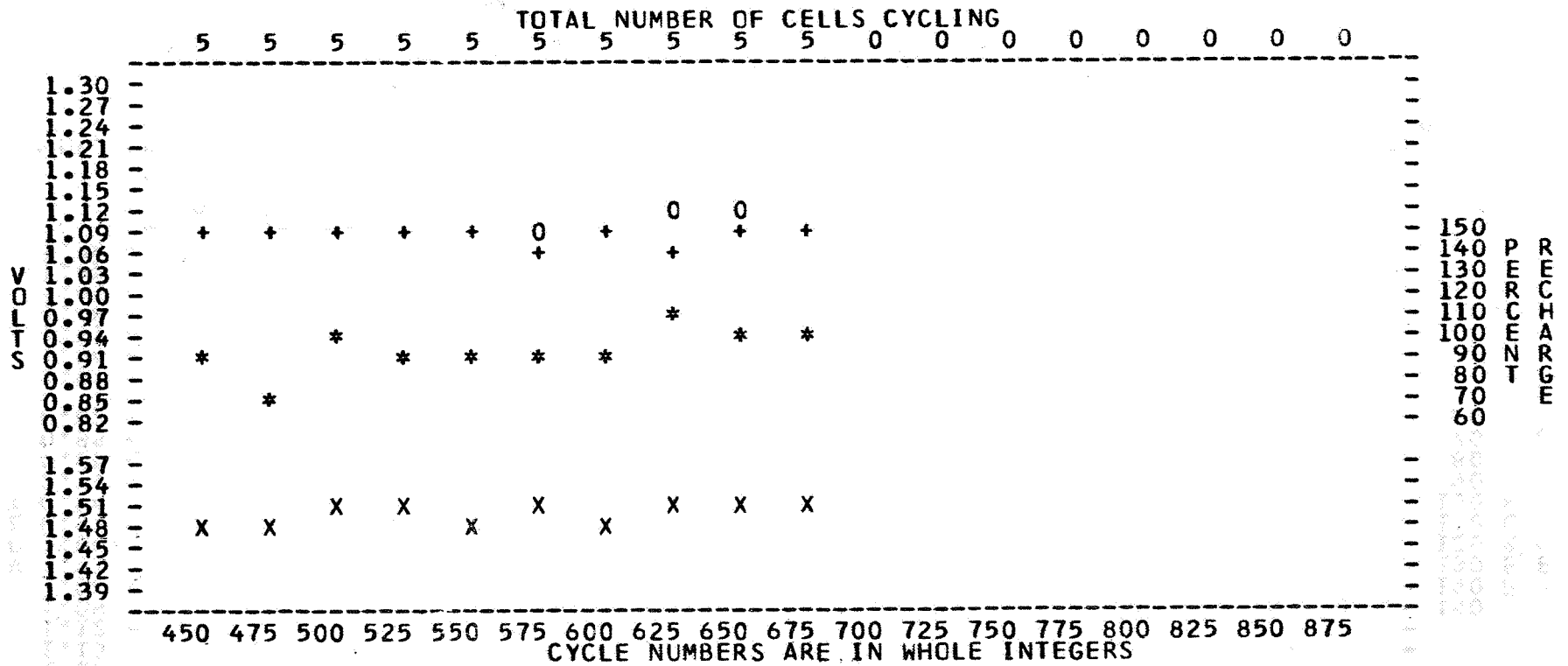
CAPACITY CHECK CYCLES
103, 193, 295, 394, 496
600,

STATUS CELLS CYCLING 5
CYCLES COMPLETED 700

FIGURE 26(A)

QE/C 69-244

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 113B
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.

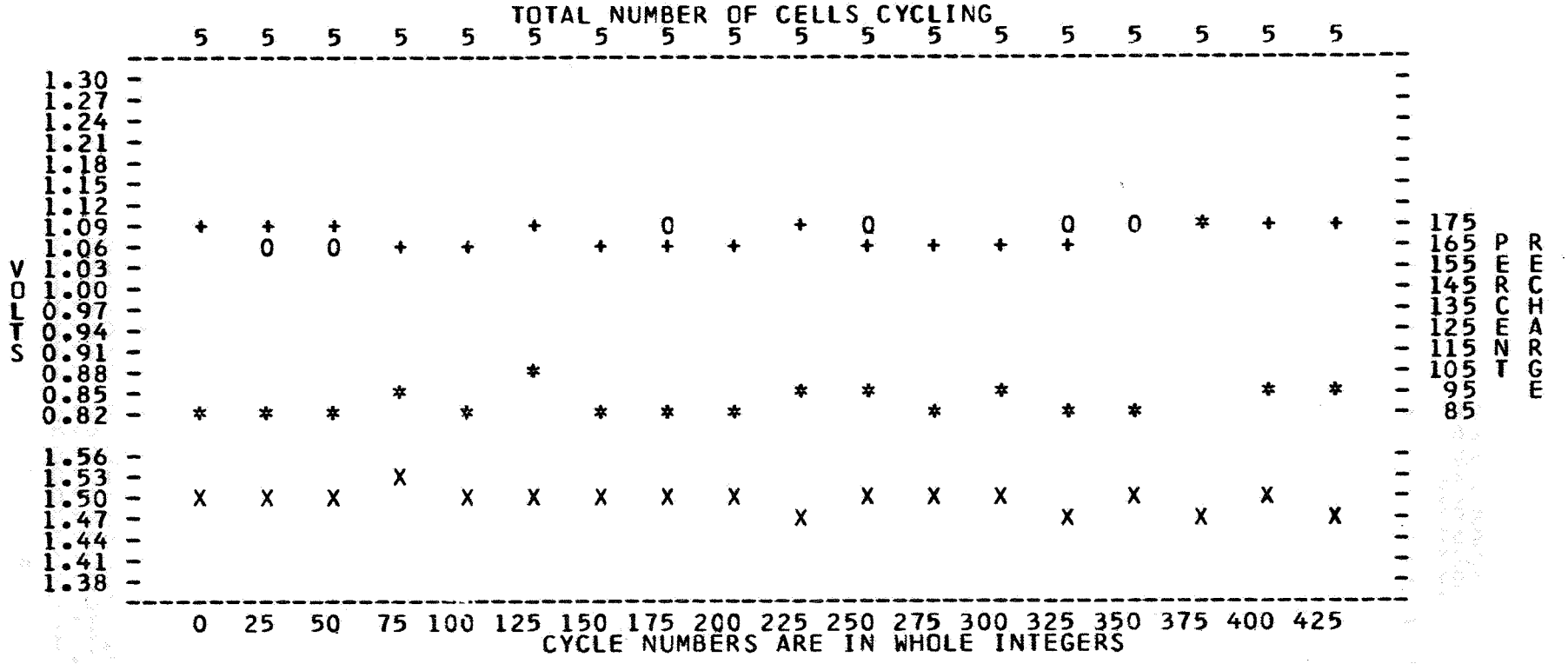
CAPACITY CHECK CYCLES
103, 193, 295, 394, 496
600,

STATUS CELLS CYCLING 5
CYCLES COMPLETED 700

FIGURE 26(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 69-244

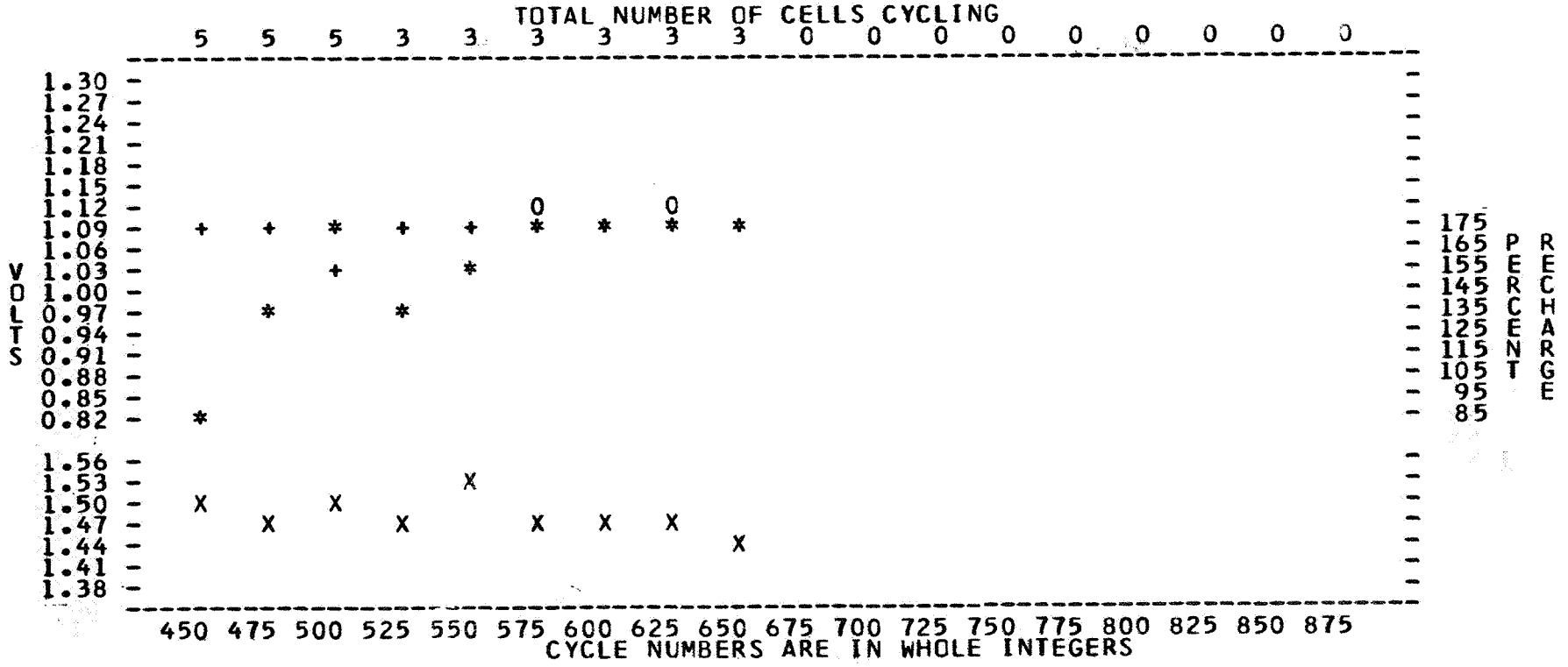


POS. NO.	CYCLE FAILED	PACK NUMBER	077B	CAPACITY CHECK CYCLES
03	500	TYPE OF CELLS	YARDNEY 5.00 AH	114, 204, 306, 405, 507
05	509	TEST TEMPERATURE	25 DEGREES C.	606,
01	661	ORBIT PERIOD	24.0 HOURS	
02	661	DEPTH OF DISCHARGE	20 PERCENT	
04	661	SPECIFIED CHARGE RATE	0.30 AMP.	

STATUS PACK FAILED
ON CYCLE NUMBER 661

FIGURE 26(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.	CYCLE FAILED
03	500
05	509
01	661
02	661
04	661

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, 405, 507
606,

STATUS PACK FAILED
ON CYCLE NUMBER 661

FIGURE 26(B) (CONTD)

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 27(A) and 27(B).) Cycling was started in January 1967. Packs 114B and 118C failed on cycles 1496 and 1505 respectively.

(a) Pack 114B: Failure of three cells, all on cycle 1496 was due to silver migration and separator deterioration.

(b) Pack 118C: Failure of three cells, all due to silver migration and separator deterioration, occurred relatively close together--at cycles 1468, 1491 and 1505 respectively.

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

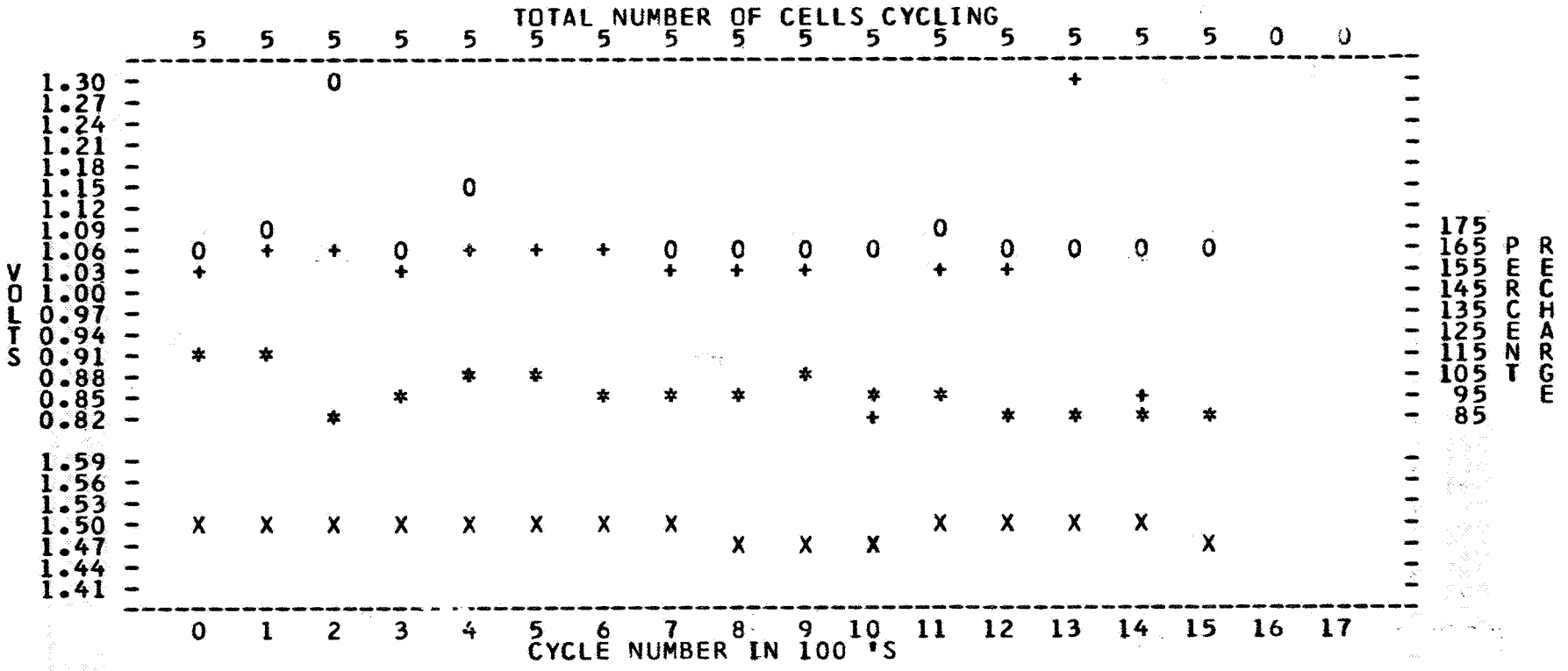
PRECYCLING AND CAPACITY CHECKS

Orbit Period	8-hour	
Temperature	0°	25°
Pack Number	114B	118C
Precycling 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
300 Days	1.17	5.07
330 Days	1.65	6.33
360 Days	1.18	5.73
390 Days	2.40	5.68
420 Days	1.00	5.97
450 Days	0.90 F	3.32 F

F - 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
03	1496
04	1496
05	1496

PACK NUMBER 114B
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 1496

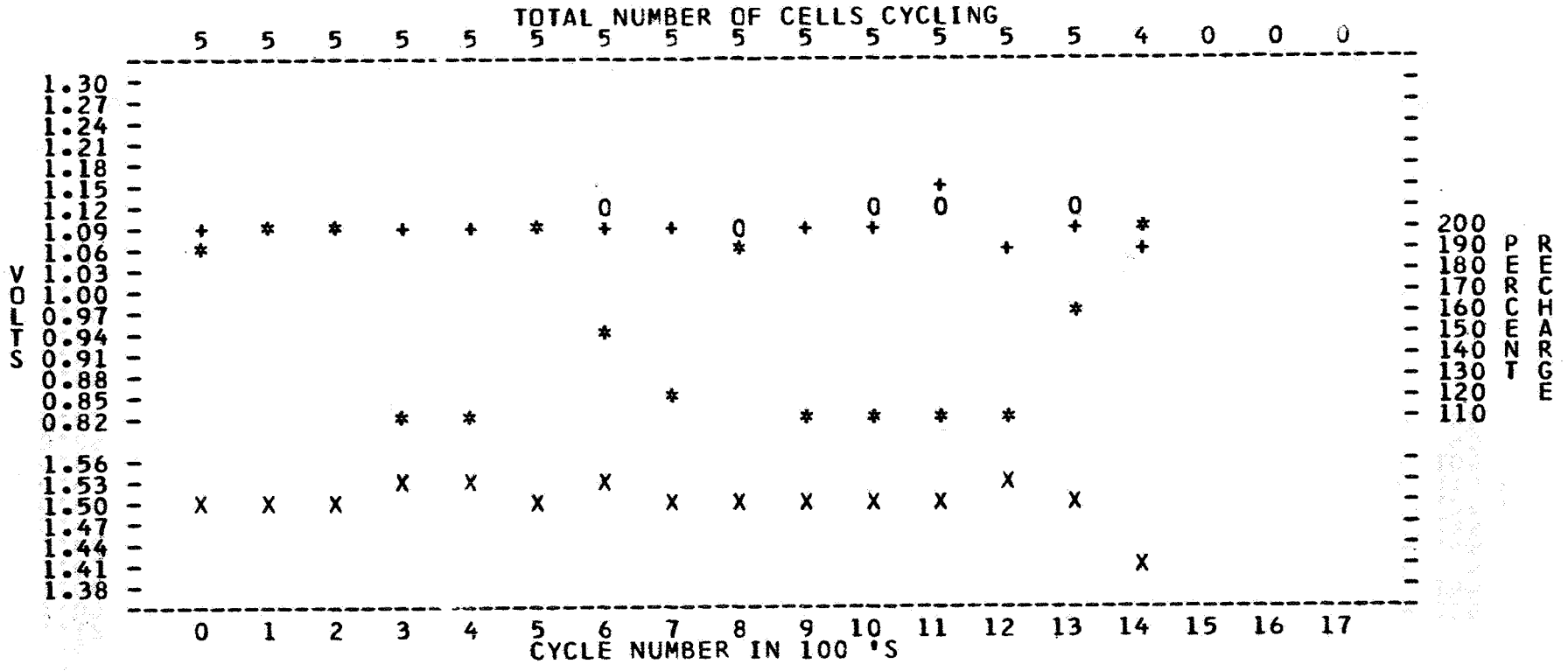
CAPACITY CHECK CYCLES

133,	238,	318,	414,	516
603,	702,	783,	882,	964
1039,	1133,	1212,	1317,	1417
0,	0,	0,	0,	0

FIGURE 27(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
01	1468
04	1491
05	1505

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.

STATUS PACK FAILED
ON CYCLE NUMBER 1505

CAPACITY CHECK CYCLES

149,	254,	334,	430,	532
619,	718,	799,	898,	980
1059,	1153,	1253,	1337,	1437
0,	0,	0,	0,	0

FIGURE 27(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:

(1) Performance on cycling: (Figure 28.) Cycling was started in May 1967. This pack failed on cycle 1759. Failure of the three cells, all due to silver migration and separator deterioration, occurred at cycles 1666, 1756 and 1759.

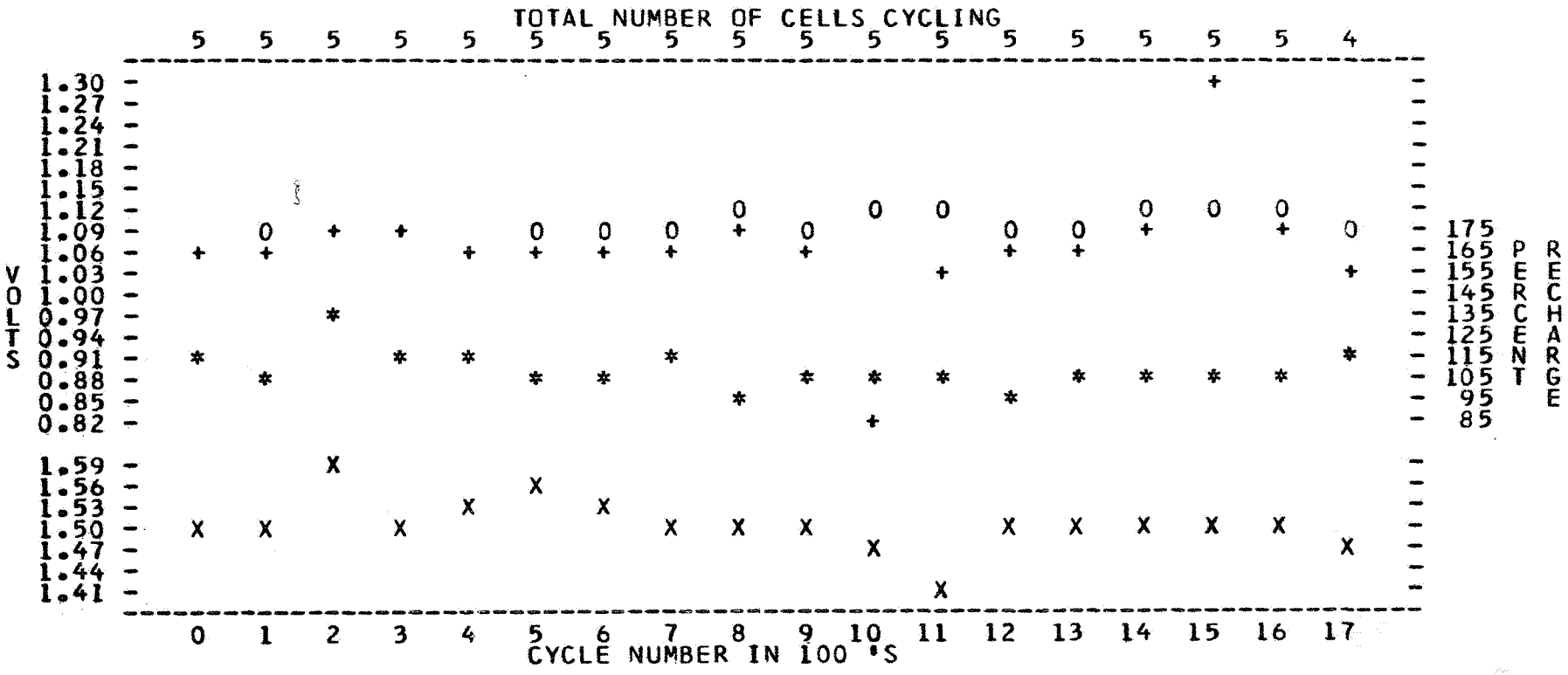
(2) Capacity checks: The ampere-hour capacities on the precycling and capacity check cycles are as follows:

Precycling Capacity	13.50		
30 Days	8.90	300 Days	10.60
60 Days	9.60	330 Days	8.75
90 Days	7.10	360 Days	5.60
120 Days	8.45	390 Days	4.35
150 Days	9.25	420 Days	5.60
180 Days	8.50	450 Days	4.65
210 Days	7.70	480 Days	3.15
240 Days	10.00	510 Days	6.05
270 Days	9.55	540 Days	3.15 F

F - 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
05	1666
04	1756
03	1759

PACK NUMBER 045D
TYPE OF CELLS YARDNEY 10.00 AH
TEST TEMPERATURE 25 DEGREES C.
ORBIT PERIOD 08.0 HOURS
DEPTH OF DISCHARGE 30 PERCENT
SPECIFIED CHARGE RATE 0.50 AMP.

CAPACITY CHECK CYCLES
96, 189, 291, 378, 477
558, 657, 740, 823, 917
996, 1101, 1201, 1286, 1380
1480, 1635, 1728, 0, 0

STATUS PACK FAILED
ON CYCLE NUMBER 1759

DISCONTINUED BY GODDARD SPACE FLIGHT CENTER

FIGURE 28

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: Cycling was started in November 1966. Packs 45B and 21B were considered as having failed on cycles 121 and 69 respectively since three of the 10 cells in each pack had by then developed internal shorts. At the request of Goddard Space Flight Center, the packs were returned for failure analysis.

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

Temperature	0°	25°
Pack Number	45B	21B
Precycling Capacity	9.26	11.46 F
100 Days	5.91 F	

F - Failed

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. Packs 21C and 45C failed on cycles 37 and 70 respectively. Several cells in each pack developed high internal pressure which resulted in breakage of those cell jars and the epoxy potting.

(2) Capacity checks: The ampere-hour capacities on precycling are as follows:

Pack Number	Precycling
21C	8.40 F
45C	9.45 F

F - Failed

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 168 and 210.

(a) Pack 57A: Low end-of-discharge cell voltages began on cycle 31 and continued erratically until the pack failed on cycle 168. 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 six 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 precycling and capacity check cycles are as follows:

Pack Number	Precycling Capacity	140 Days Discharge #1	#2	
57A	13.8	5.9	8.6	Failed
33A	13.5	11.2	12.0	Failed

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 potted 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:

(1) Performance on cycling: Cycling was started in January 1966. Following change of test temperature from -20° C to 40° C at cycle 214, Pack 85B operated until failure on cycle 2375. Packs 97B and 82B failed on cycles 4481 and 4559 respectively.

(a) 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 Packs 97B and 82B was also approximately 1.06 volts per cell, average.

(b) Pack 85B: Individual cell failures, all caused by silver penetration of the separators, occurred at cycles 1978, 2245 and two at cycle 2375.

(c) Pack 97B: Individual cell failures, all caused by silver penetration of the separators, occurred at cycles 2972, 3186 and 4481.

(d) Pack 82B: Individual cell failures, all caused by silver penetration of the separators, occurred at cycles 4467 and two at 4559.

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

Orbit Period	1.5-hour		
Temperature	-20°*	0°	25°
Depth of Discharge	25%	25%	25%
Pack Number	85B	97B	82B
Precycling 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 F
352 Days	9.60 F	3.70 F	

F - Failed
* Cycle 214 changed to 40° C
** Missed 88-day capacity check due to low voltage on several cells.

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 currents are supplied by a unit described in Section I, Paragraph IV.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 46 cycles.

c. Test Results:

(1) Performance on cycling: (Figures 29(A) through 29(D).) Cycling was started in March 1966. Packs 74B, 88D and 108B have completed 15,385, 14,774 and 15,688 cycles to date with one cell failure on Pack 88D. Pack 98B failed on cycle 12,247.

(a) Pack 74B: Initially, while cycling at -20° C, these cells developed pressures in excess of 150 psig. After release of this pressure following cycles 4 and 6, and with the reduction of the charge rate from 1.25 to 1.00 ampere, the internal pressure remained low for over 6000 cycles. At cycle 6294, about 8 days after the capacity checks following 352 days of cycling, the pressure of cell number 1 was released. At cycle 11,011, about 40 days after the capacity checks following 616 days of cycling, the pressure was released on each of the five cells. Similarly at cycle 13,062, following the capacity checks after 792 days of cycling, the pressure in cell number 1 was released; and that of each of the five cells was released at cycle 14,450 following the capacity checks after 880 days of cycling. There were no cell failures.

(b) Pack 88D: Initially, while cycling at -20° C, these cells developed pressures in excess of 150 psig. After release of this pressure following cycles 3 and 5, the charge rate was reduced from 1.25 to 1.00 ampere. The internal pressure increased sufficiently in cell number 2 to release it at cycle 46, at which time the depth of cycle discharges was reduced from 60 to 25 percent. It was necessary to relieve each of the five cells of excessive pressure at cycle 10,399, approximately 40 days after the capacity checks following 616 days of cycling; and at cycle 13,839, following the capacity checks after 880 days of cycling. The one failed cell showed severe migration of negative plate material, and blistering on the positive plates.

(c) Pack 98B: The three cells which failed at cycles 5033, 5513 and 12,247 respectively, showed severe migration of negative material and blistering of the positive plates. Two of these cells had developed high internal pressure as evidenced by bulged cases.

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

PRECYCLING AND CAPACITY CHECKS

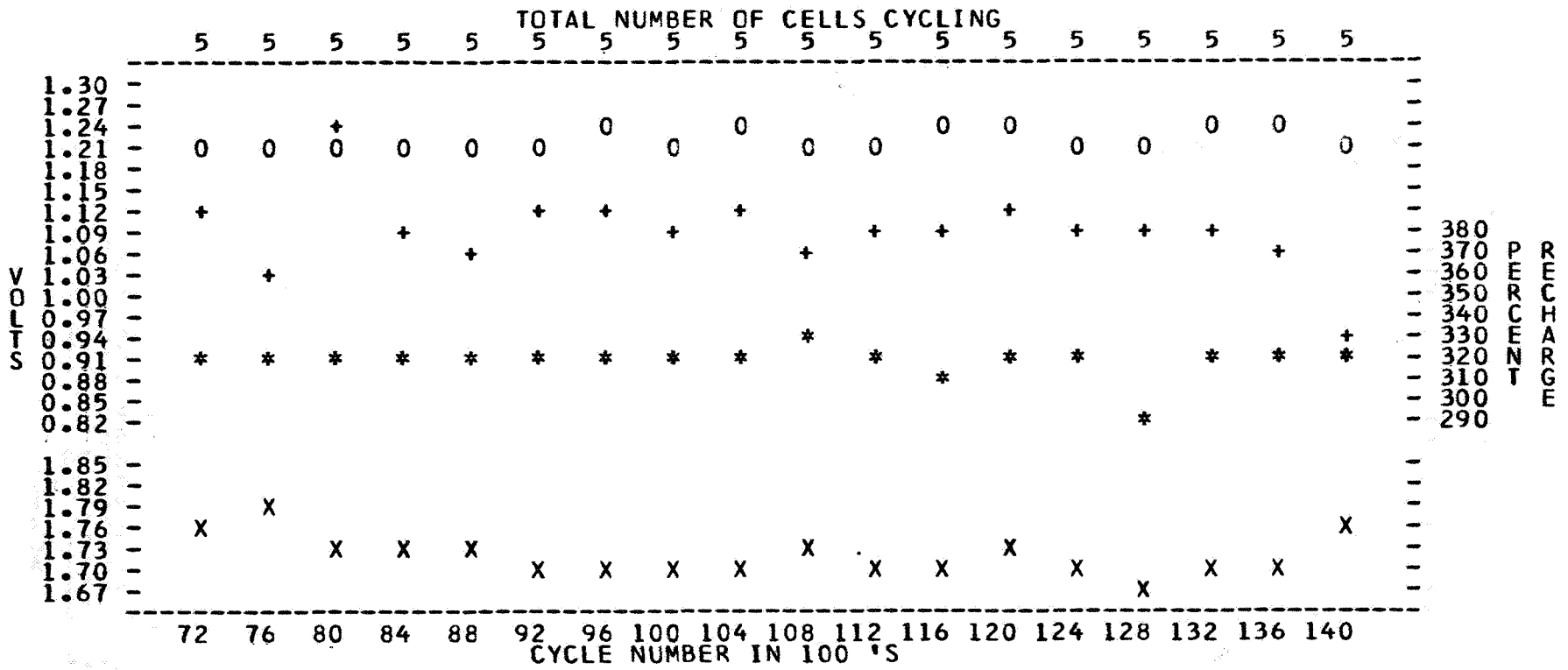
Orbit Period		1.5-hour			
Temperature		-20°	-20°	0°	0°
Depth of Discharge		25%	60%*	25%	60%
Pack Number		74B	88D	108B	98B
Precycling Capacity		1.43	1.28	1.78	1.83
88 Days	Disch #1	0.54	0.52	1.67	1.58
	Disch #2	0.39	0.36	1.76	1.60
176 Days	Disch #1	0.41	0.40	1.69	1.53
	Disch #2	0.42	0.52	1.59	1.39
264 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
616 Days	Disch #1	0.35	0.35	1.19	0.97
	Disch #2	0.41	0.36	0.92	0.99
704 Days	Disch #1	0.31	0.34	1.09	0.86
	Disch #2	0.34	0.31	0.55	0.81 F
792 Days	Disch #1	0.28	0.27	1.10	
	Disch #2	0.29	0.28	1.01	
880 Days	Disch #1	0.25	0.26	1.13	
	Disch #2	0.27	0.27	0.87	

* Depth of discharge on Pack 88D was reduced to 25% after 46 cycles.

F - 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 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.

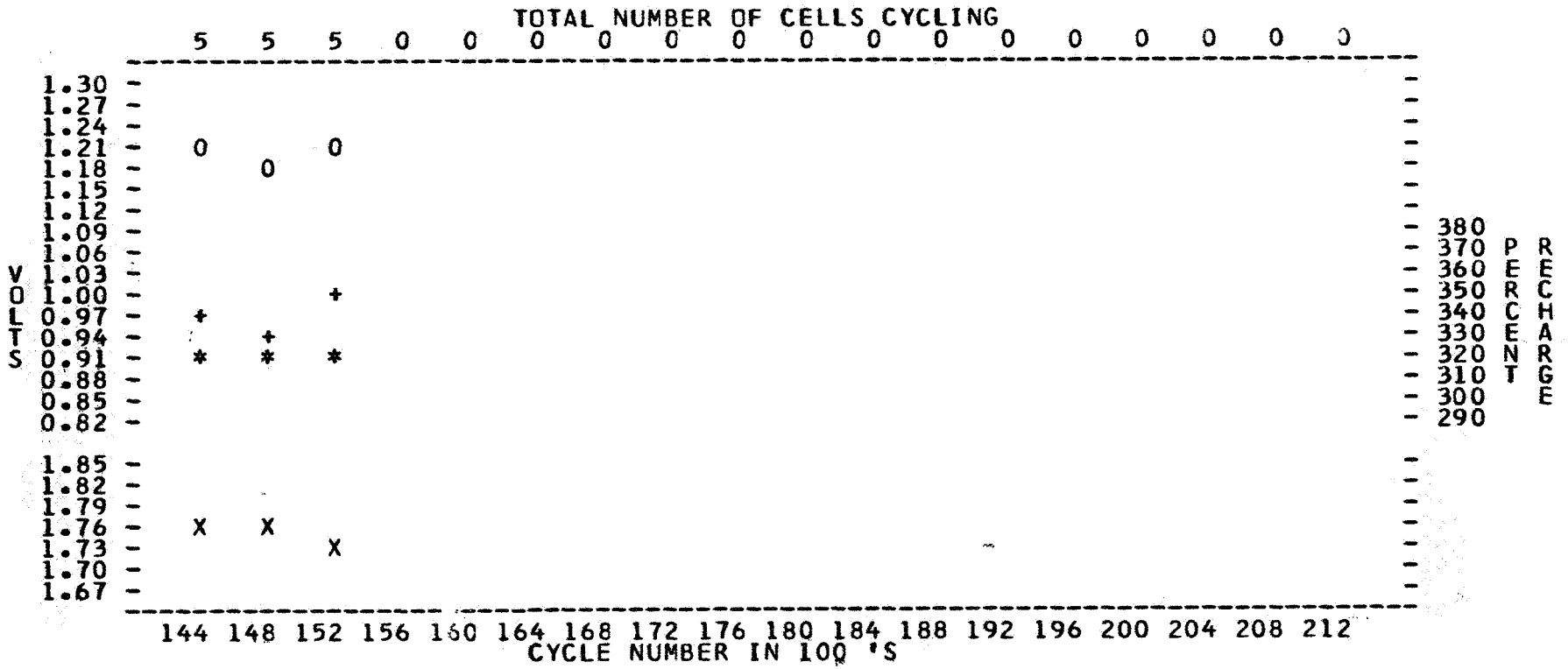
STATUS CELLS CYCLING 5
CYCLES COMPLETED 15385

CAPACITY CHECK CYCLES
1324, 2593, 4532, 6165, 7541
8948,10354,11791,13057,14447
0,

FIGURE 29(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 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.

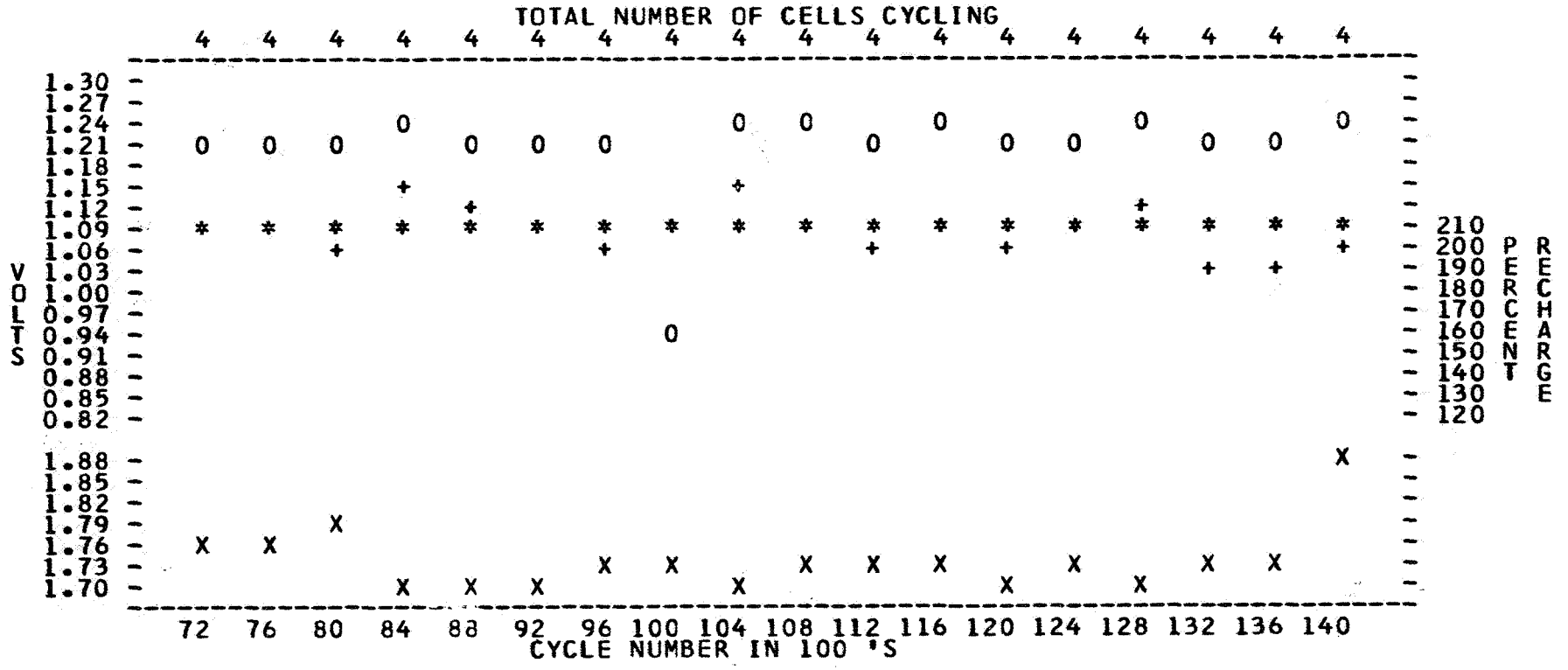
STATUS CELLS CYCLING 5
CYCLES COMPLETED 15385

CAPACITY CHECK CYCLES
1324, 2593, 4532, 6165, 7541
8948,10354,11791,13057,14447
0,

FIGURE 29(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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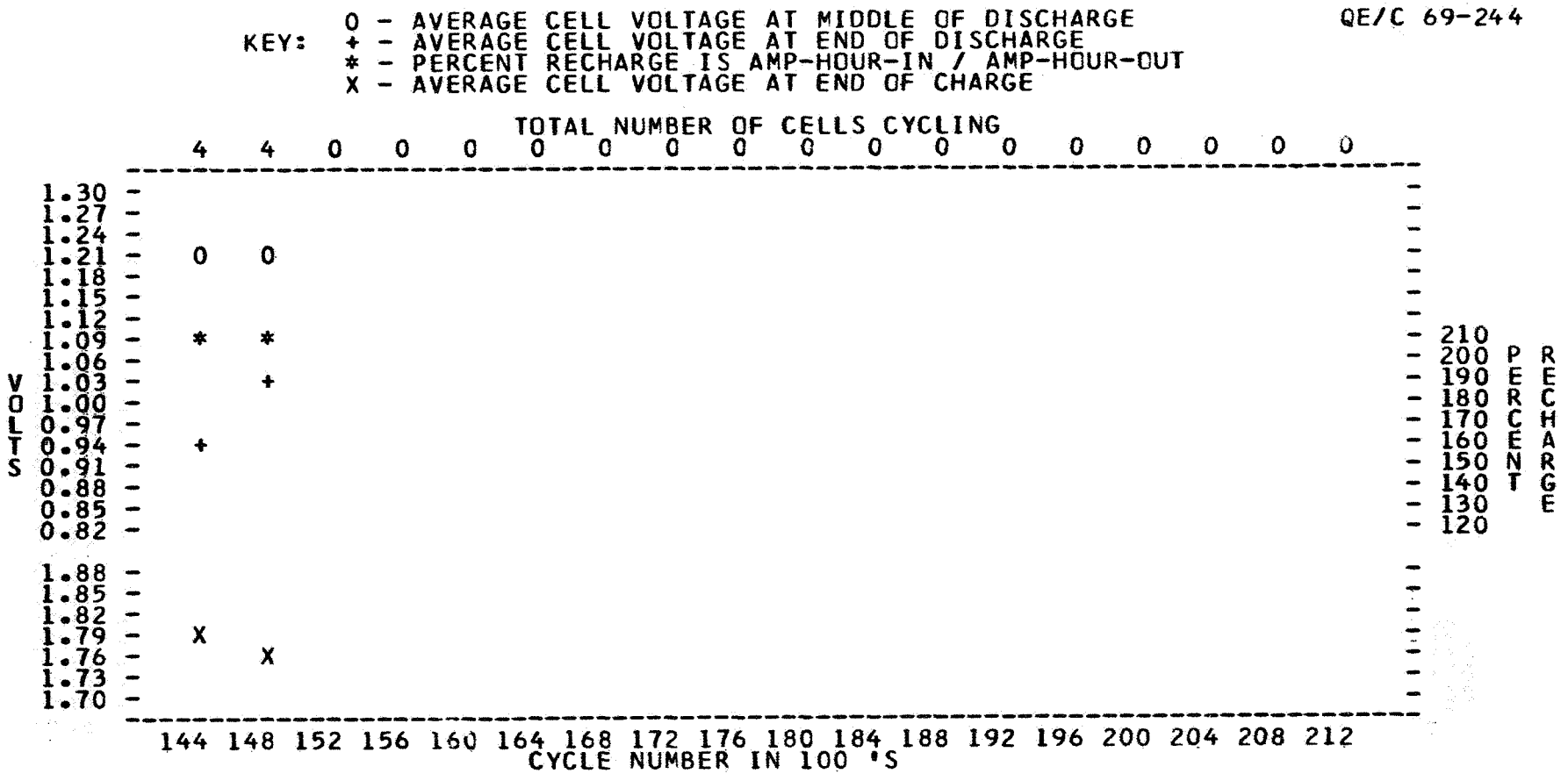
POS. NO. 05 CYCLE FAILED 1897

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 14774

CAPACITY CHECK CYCLES
914, 1992, 3921, 5554, 6930
8367,

FIGURE 29(B)



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.

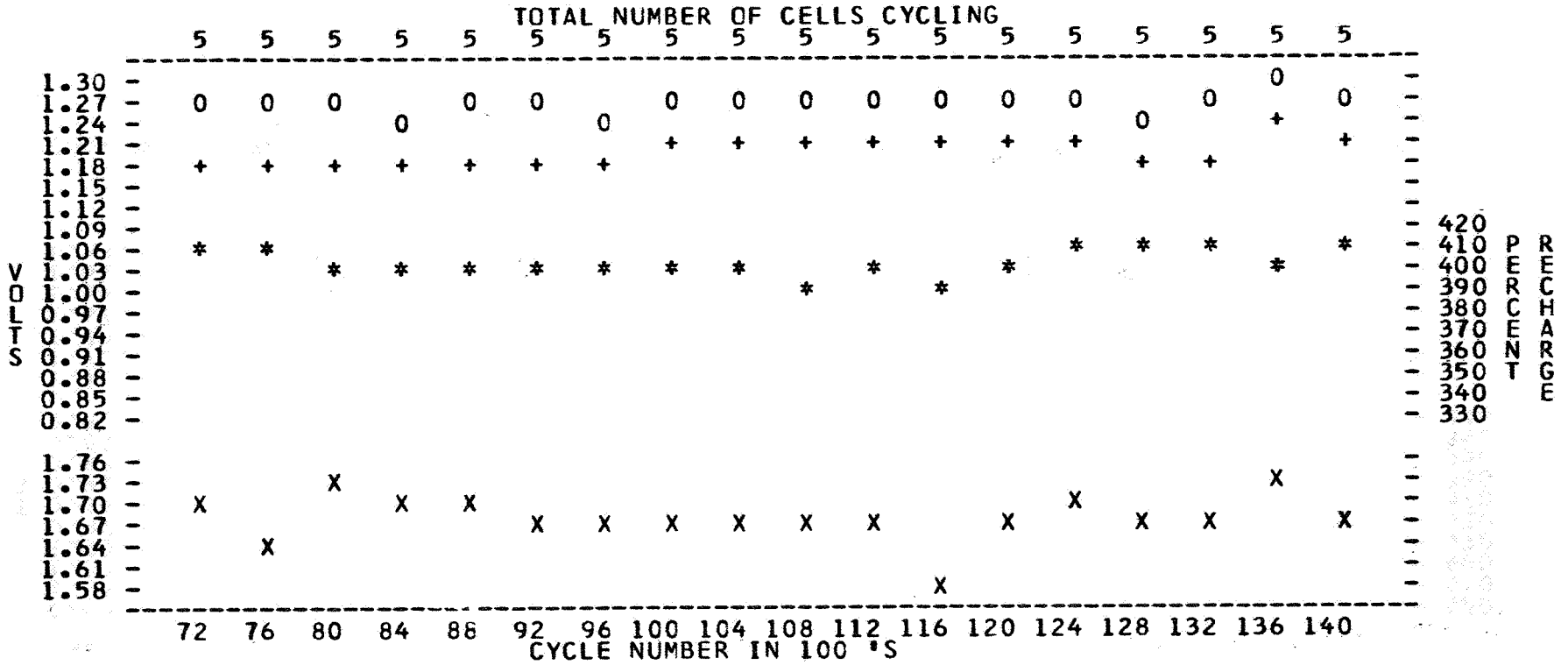
STATUS CELLS CYCLING 4
CYCLES COMPLETED 14774

CAPACITY CHECK CYCLES
914, 1992, 3921, 5554, 6930
8367,

FIGURE 29(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

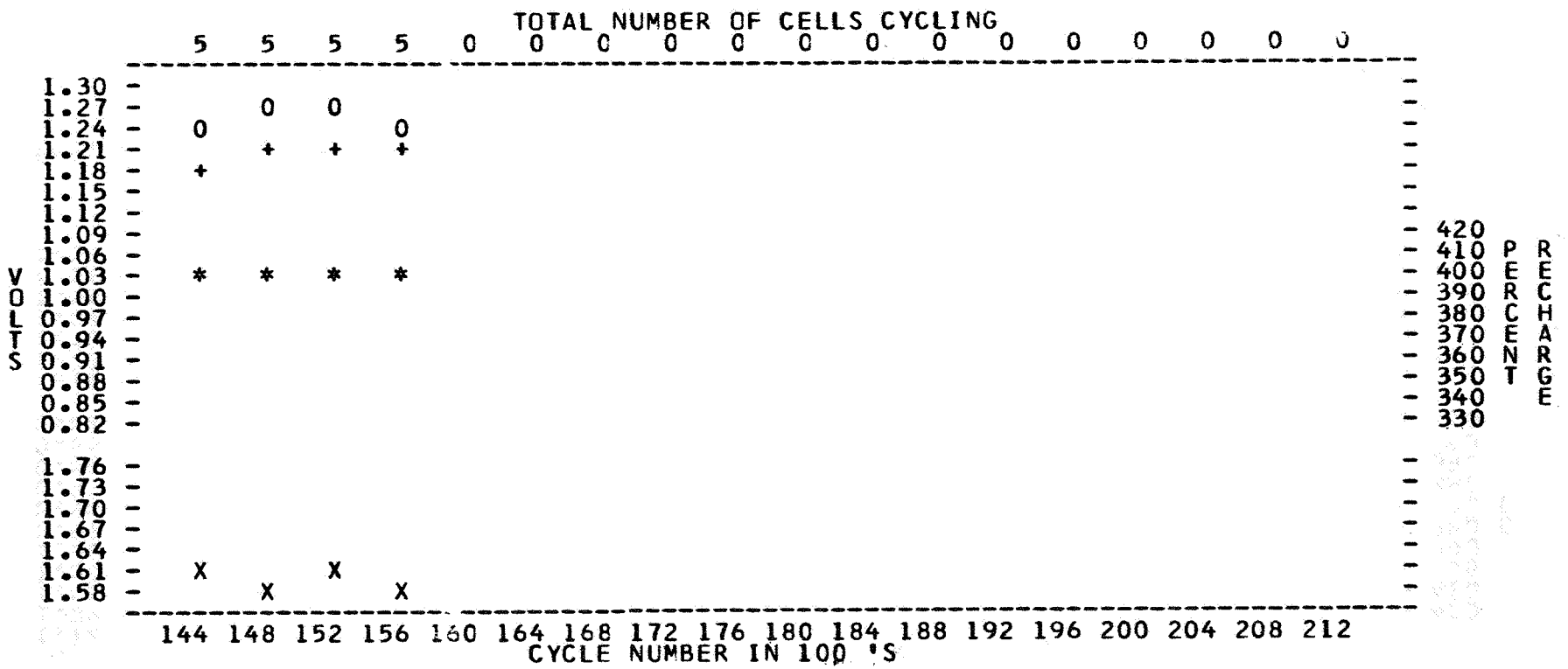
PACK NUMBER 108B
TYPE OF CELLS GULTON 1.25 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 1.25 AMP.

STATUS CELLS CYCLING 5
CYCLES COMPLETED 15688

CAPACITY CHECK CYCLES
1618, 2996, 4935, 6533, 7860
9350,10753,12208,13599,14974
0,

FIGURE 29(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



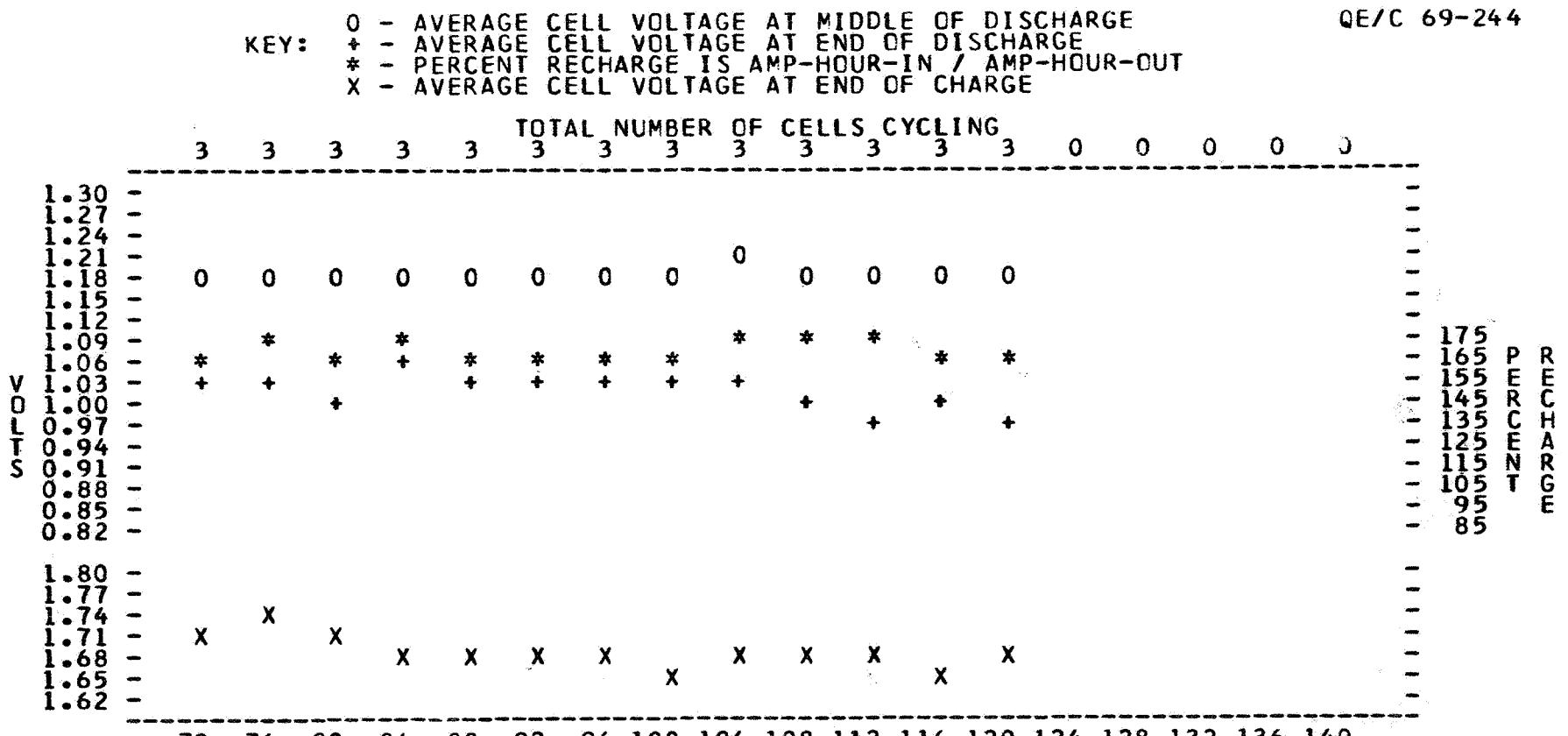
POS. NO. CYCLE FAILED

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.

STATUS CELLS CYCLING 5
CYCLES COMPLETED 15688

CAPACITY CHECK CYCLES
1618, 2996, 4935, 6533, 7860
9350,10753,12208,13599,14974
0,

FIGURE 29(C) (CONTD)



POS. NO.	CYCLE FAILED
05	5033
04	5513
02	12247

PACK NUMBER 0988
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 PACK FAILED
ON CYCLE NUMBER 12247

CAPACITY CHECK CYCLES
1618, 2996, 4952, 6169, 7496
8903,10357,11844,

FIGURE 29(D)

B. Auxiliary Electrode: Nickel-cadmium cells have been developed with an auxiliary electrode whose voltage, with respect to the negative 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 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 of each cell in the pack to reduce the charging rate after the cells have received the desired amount of recharge. The circuit is designed to monitor the auxiliary electrode voltage of each cell while the 5-cell pack is being charged. As the auxiliary electrode voltage of any one cell of the pack approaches a preset value, the circuit begins to reduce the charge current. When the auxiliary electrode voltage of any cell reaches the predetermined voltage (trip voltage), the charge current will be reduced to a preset trickle or to zero. The charge and discharge currents are supplied by a unit described in Section I, Paragraph IV.B.

c. Test Parameters:

Pack Number	Test Temperature	Percent Depth of Discharge	Trip 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	12	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 30(A) and 30(B).) Cycling was started in February 1965.

(a) Packs 59A and 71A, cycling at 0° C, failed on cycles 14,863 and 5753 respectively. Pack 71A, cycling at 40 percent depth of discharge, delivered only 37.5 percent of the number of cycles delivered by Pack 59A cycling at 25 percent depth of discharge.

1. Pack 59A: Failure of one cell at cycle 3202 was due to migration of negative plate material. The cell had high internal pressure as evidenced by a bulge, a weight loss of 1.4 grams, and pressure release upon opening the cell. The two other cell failures, which occurred at cycle 14,863 showed migration of negative plate material, separator deterioration, blistering of the positive plates, and leakage as evidenced by carbonate deposits around the ceramic seals and weight losses of 3.0 and 1.5 grams.

2. Pack 71A: Failure of one cell at cycle 2993 was due to a combination of blistering of the positive plates and migration of negative plate material to the pressure areas of contact of the blisters. This cell had extraneous positive material, high pressure and leakage as noted by bulging of the case, carbonate deposits around the ceramic seals and a weight loss of 8.7 grams. The second failed cell, at cycle 5070, showed migration of negative material, separator deterioration, blisters on the positive plates, and leakage as evidenced by a weight loss of 5.9 grams. The two cells which failed at cycle 5753 showed migration of negative material,

separator deterioration, blisters on the positive plates, and leakage as evidenced by a weight loss of 4.0 grams on one cell with release of pressure upon opening, and a weight loss of 2.1 grams on the other cell.

(b) Packs 23A and 11A, cycling at 25° C, failed on cycles 15,713 and 7743 respectively. Pack 11A, cycling at 40 percent depth of discharge, delivered about 49 percent of the number of cycles delivered by Pack 23A cycling at 25 percent depth of discharge.

1. Pack 23A: Failure of one cell at cycle 10,338 was due to migration of negative material, separator deterioration and blisters on the positive plates. There was some leakage as evidenced by a deposit around the ceramic seal. The two cell failures at cycle 15,711 were caused by separator deterioration, migration of negative material and blisters on the positive plates. These two cells also had leakage as evidenced by deposits around the ceramic seals, and a weight loss of 2.9 grams on one cell.

2. Pack 11A: Failure of one cell at cycle 2755 was due to a ceramic short. There was some separator deterioration and blisters on the positive plates as well as leakage as evidenced by a weight loss of 1.3 grams. Failure of two other cells on cycle 7743 was due to separator deterioration, migration of negative material and blistering of the positive plates.

(c) Packs 35A and 47A, cycling at 40° C failed on cycles 12,511 and 5502 respectively. Pack 47A, cycling at 25 percent depth of discharge, delivered about 44 percent of the number of cycles delivered by Pack 35A cycling at 15 percent depth of discharge.

1. Pack 35A: Failure of the three cells at cycles 11,471, 12,224 and 12,511 was due to separator deterioration and migration of negative material with blisters on the positive plates of two cells. The three cells exhibited some high pressure as evidenced by pressure release upon opening the cells, of which the cases of two were bulged. Some leakage existed on two cells as evidenced by deposits around the ceramic seals.

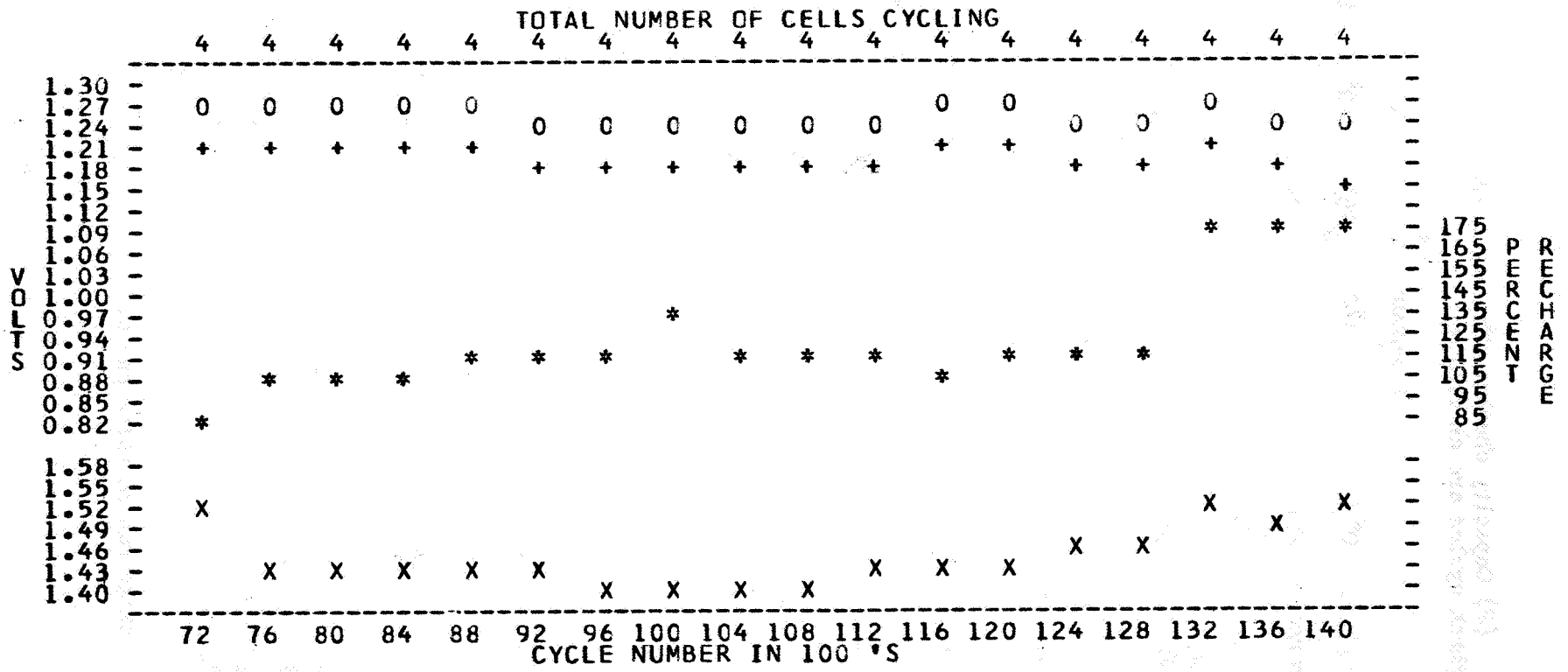
2. Pack 47A: Failure of the three cells at cycles 5200, 5223 and 5502 was due to separator deterioration, migration of negative material and blisters on the positive plates. Two cells had some weak welds between tabs and positive plates. Two cells had some leakage as evidenced by deposits around the ceramic seals, one of which had some internal pressure which was released upon opening the cell.

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

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 F	5.20	6.20	1.85	2.25 F
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 F	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 F	
880 Days	Disch #1	1.90		2.50			
	Disch #2	2.50 F		1.50			
968 Days	Disch #1			1.25			
	Disch #2			1.00			
1056 Days	Disch #1			1.23			
	Disch #2			0.78 F			

* Only one discharge run on these packs.
F - 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
03	3202
02	14863
05	14863

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.

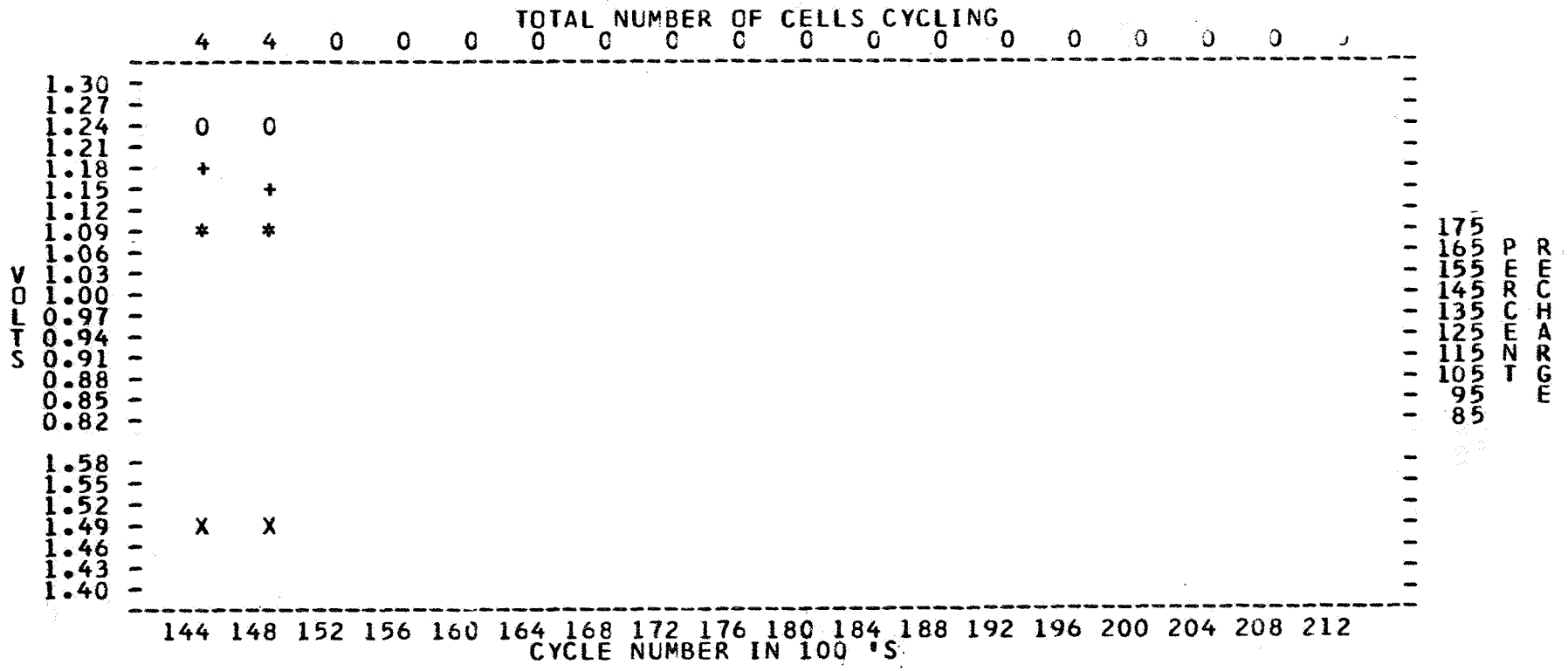
STATUS PACK FAILED
ON CYCLE NUMBER 14863

CAPACITY CHECK CYCLES
635, 2040, 3104, 4749, 6280
7310, 8689,10167,11517,12924
14329,

RESISTOR VALUES: 10, 10, 10, 10, 10, OHMS.

FIGURE 30(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
03	3202
02	14863
05	14863

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 PACK FAILED
ON CYCLE NUMBER 14863

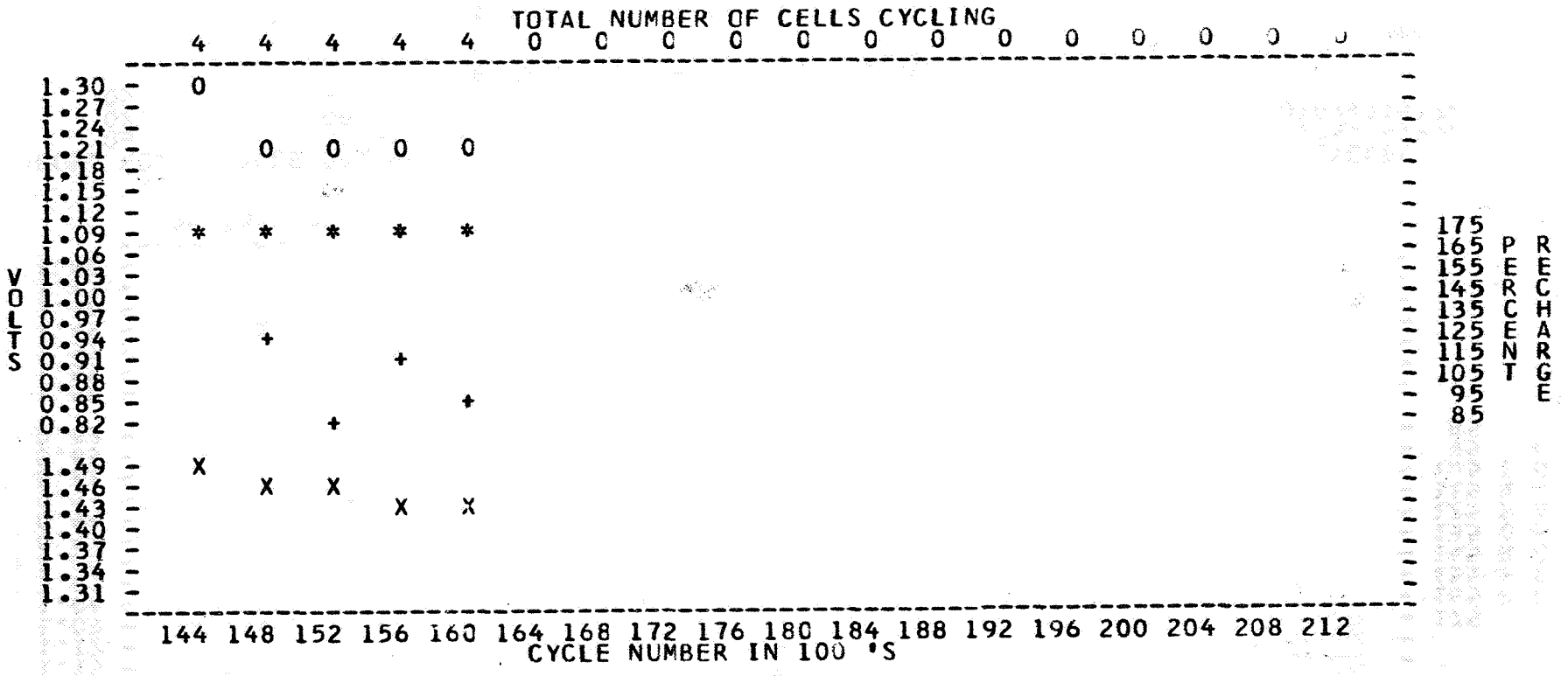
CAPACITY CHECK CYCLES
635, 2040, 3104, 4749, 6280
7310, 8689,10167,11517,12924
14329,

RESISTOR VALUES: 10, 10, 10, 10, 10, OHMS.

FIGURE 30(A) (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
05	10338
04	15713
01	15713

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
14306,15711,

STATUS PACK FAILED
ON CYCLE NUMBER 15713

RESISTOR VALUES AFTER 853 CYCLES: 12, 12, 20, 29, 24 OHMS.

FIGURE 30(B)

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 of each cell in the pack to reduce the charging rate after the cells have received the desired amount of recharge. The circuit is designed to monitor the auxiliary electrode voltage of each cell while the 5-cell pack is being charged. As the auxiliary electrode voltage of any one cell of the pack approaches a preset value, the circuit begins to reduce the charge current. When the auxiliary electrode voltage of any cell reaches the predetermined voltage (trip voltage), the charge current is reduced to a preset trickle or to zero. The charge and discharge currents are supplied by a unit described in Section I, Paragraph IV.B.

c. Test Parameters:

Pack Number	Test Temperature	Percent Depth of Discharge	Trip 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. After 260 days, the temperature cycle period was increased to 48 hours; all other parameters remained the same.

d. Test Results:

(1) Performance on cycling: (Figures 31(A) through 31(C).) Cycling was started in April 1967. Pack 48B failed on cycle 6156. Packs 24C and 60B have completed 9495 and 9514 cycles respectively with no cell failures.

(a) From the test data obtained to date the auxiliary electrode, when used for charge control, operates satisfactorily over the range of temperatures under which these packs were operated, without temperature compensation.

(b) All cells in Pack 48B, operating at 40 percnet depth of discharge failed on or before cycle 6156. The first cell failure (cycle 3669) resulted from the shorting together of the positive and auxiliary electrodes due to insufficient separator between one edge of the positive plates and the auxiliary electrode. This cell also showed severe separator deterioration, migration of negative material and blistered positive plates. The second cell failure (cycle 6139) resulted from a shorting condition caused by a piece of extraneous positive material, excessive migration of negative material and separator deterioration, particularly at that point; and the positive plates were blistered. This cell also had high pressure (bulged case), leakage as evidenced by a deposit on the welded seam, and a weak weld between the auxiliary electrode and the bracket on the inside wall of the cell. The remaining three cells failed on cycle 6156, due to excessive separator deterioration, and migration of negative material. These three cells had blistered positive plates and high internal pressure as evidenced by their bulged cases. Two of these cells indicated leaks by deposits around the ceramic seals, one of which also had a weak weld between the auxiliary electrode and the bracket on the inside wall of the cell. These weak welds may be the result of failure to remove active material from the grid of the auxiliary electrode before welding it to the bracket.

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

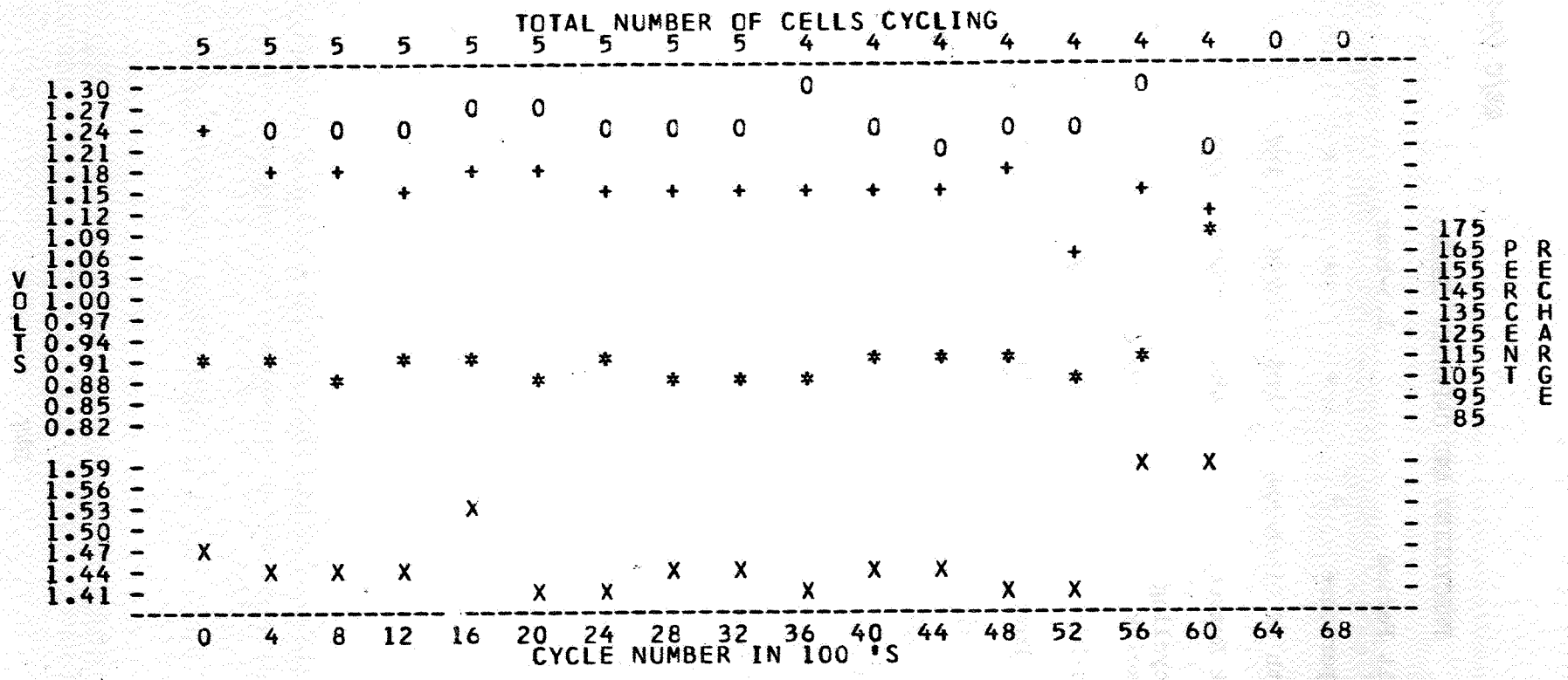
PRECYCLING AND CAPACITY CHECKS

Orbit Period		1.5-hour	
Temperature	*	*	*
Depth of Discharge	40%	25%	15%
Pack Number	48B	24C	60B
Precycling Capacity	7.40	7.20	7.45
88 Days	3.68	6.90	7.02
176 Days	2.80	6.55	7.20
264 Days	3.76	6.30	6.45
352 Days	3.20	4.15	7.14
440 Days	3.84 F	3.25	6.33
528 Days		3.10	6.63
616 Days			5.61

* All capacity checks are run at 25° C.

F - 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
01	3669
04	6156

PACK NUMBER 048B
TYPE OF CELLS GULTON 6.00 AH
TEST TEMPERATURE 0/40 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 40 PERCENT
SPECIFIED CHARGE RATE 4.80 AMP.

STATUS CELLS CYCLING 4
CYCLES COMPLETED 6156

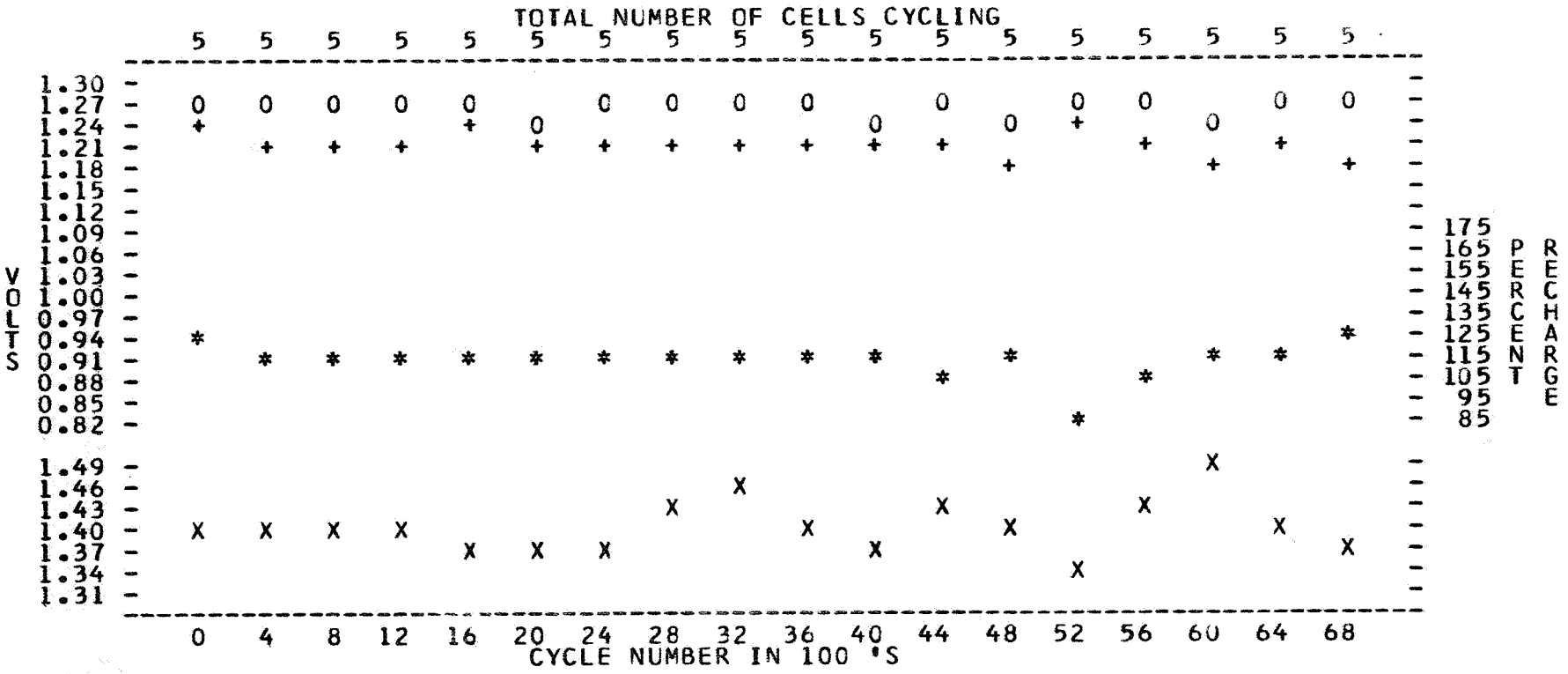
CAPACITY CHECK CYCLES
1262, 2671, 4066, 4974, 6139
0,

TEMPERATURE CYCLING CHANGED TO 48 HOURS CYCLE 4068.
RESISTORS VALUES: 6.8, 6.8, 6.8, 6.8, 6.8 OHMS

FIGURE 31(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 024C
TYPE OF CELLS GULTON 6.00 AH
TEST TEMPERATURE 0/40 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 3.00 AMP.

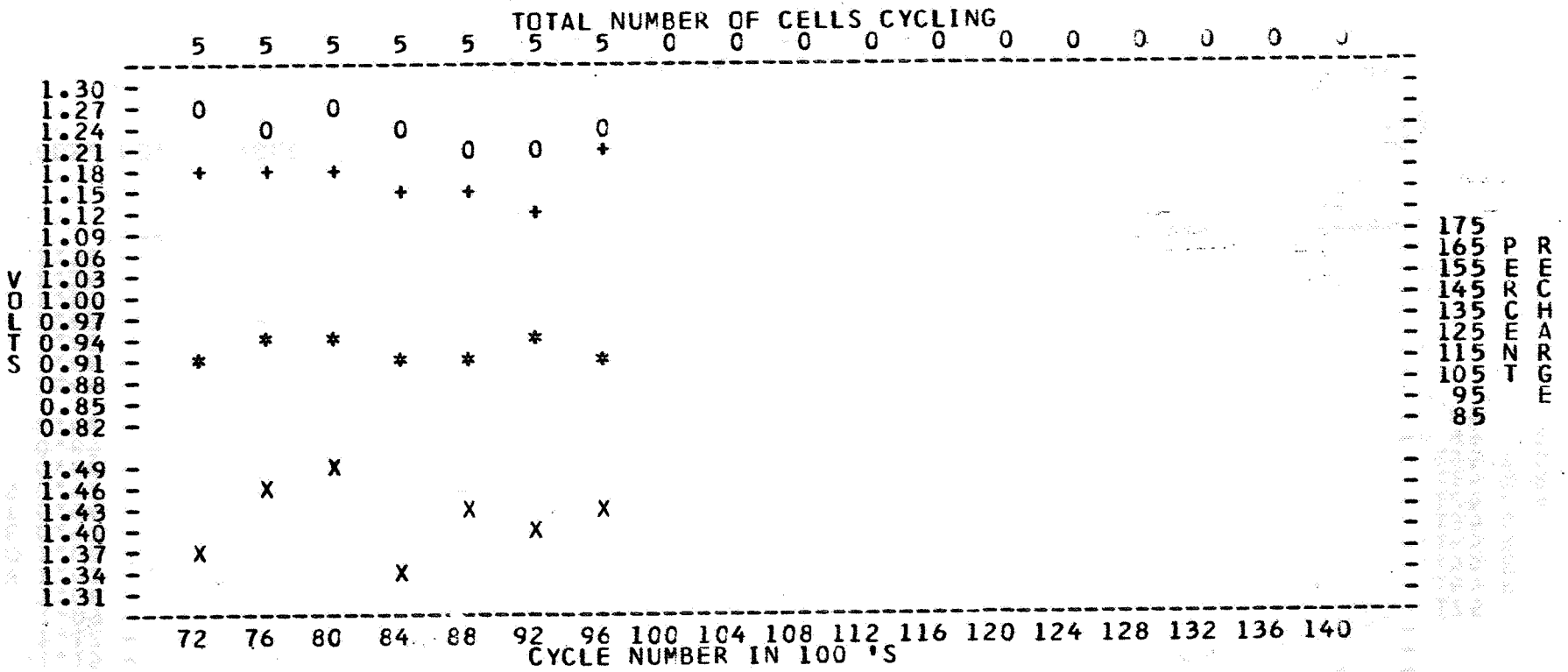
STATUS CELLS CYCLING 5
CYCLES COMPLETED 9495

CAPACITY CHECK CYCLES
1262, 2671, 4082, 5423, 6870
8217,

TEMPERATURE CYCLING CHANGED TO 48 HOURS CYCLE 4101
RESISTOR VALUES:6.8,6.8,6.8,6.8,6.8 OHMS.

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



POS. NO. CYCLE FAILED

PACK NUMBER 024C
TYPE OF CELLS GULTON 6.00 AH
TEST TEMPERATURE 0/40 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 3.00 AMP.

STATUS CELLS CYCLING 5
CYCLES COMPLETED 9495

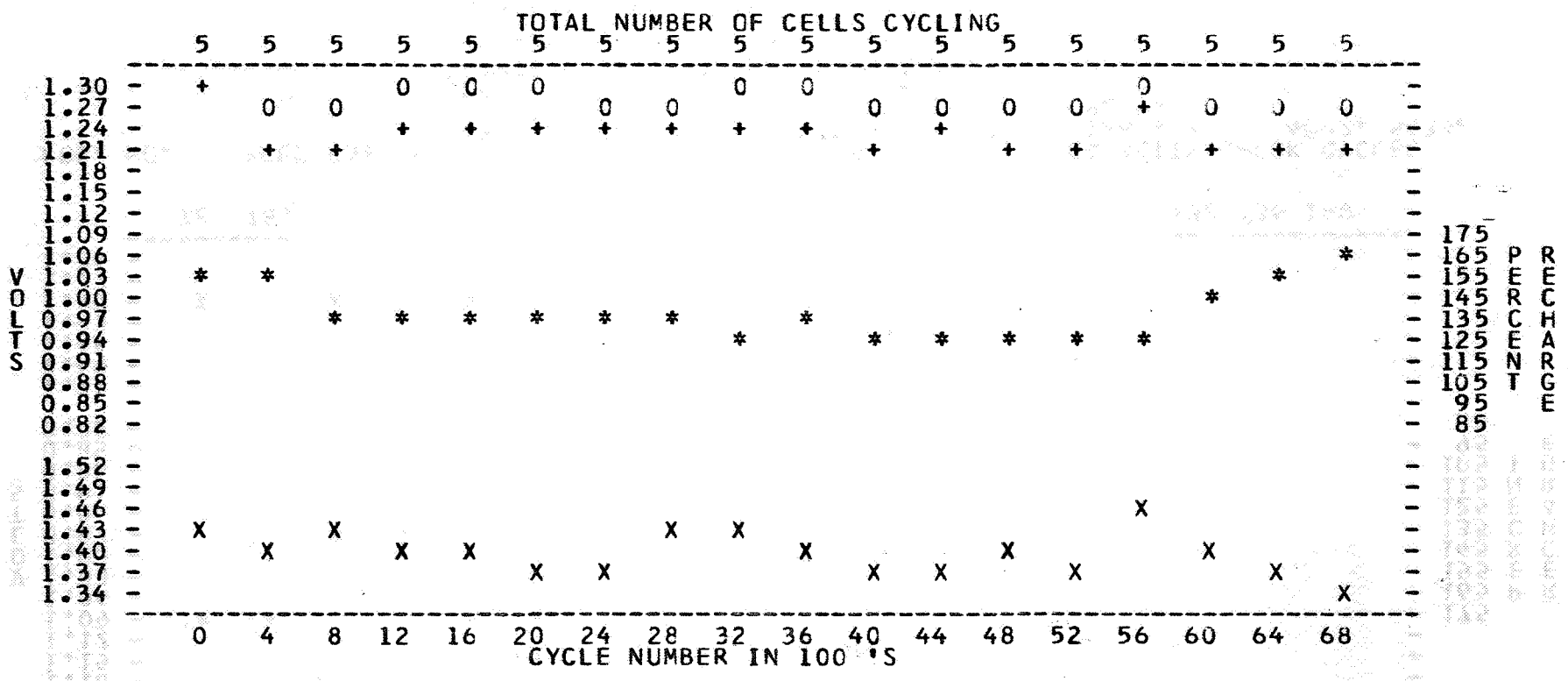
CAPACITY CHECK CYCLES
1262, 2671, 4082, 5423, 6870
8217,

TEMPERATURE CYCLING CHANGED TO 48 HOURS CYCLE 4101
RESISTOR VALUES:6.8,6.8,6.8,6.8,6.8 OHMS.

FIGURE 31(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 060B
TYPE OF CELLS GULTON 6.00 AH
TEST TEMPERATURE 0/40 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 15 PERCENT
SPECIFIED CHARGE RATE 1.80 AMP.

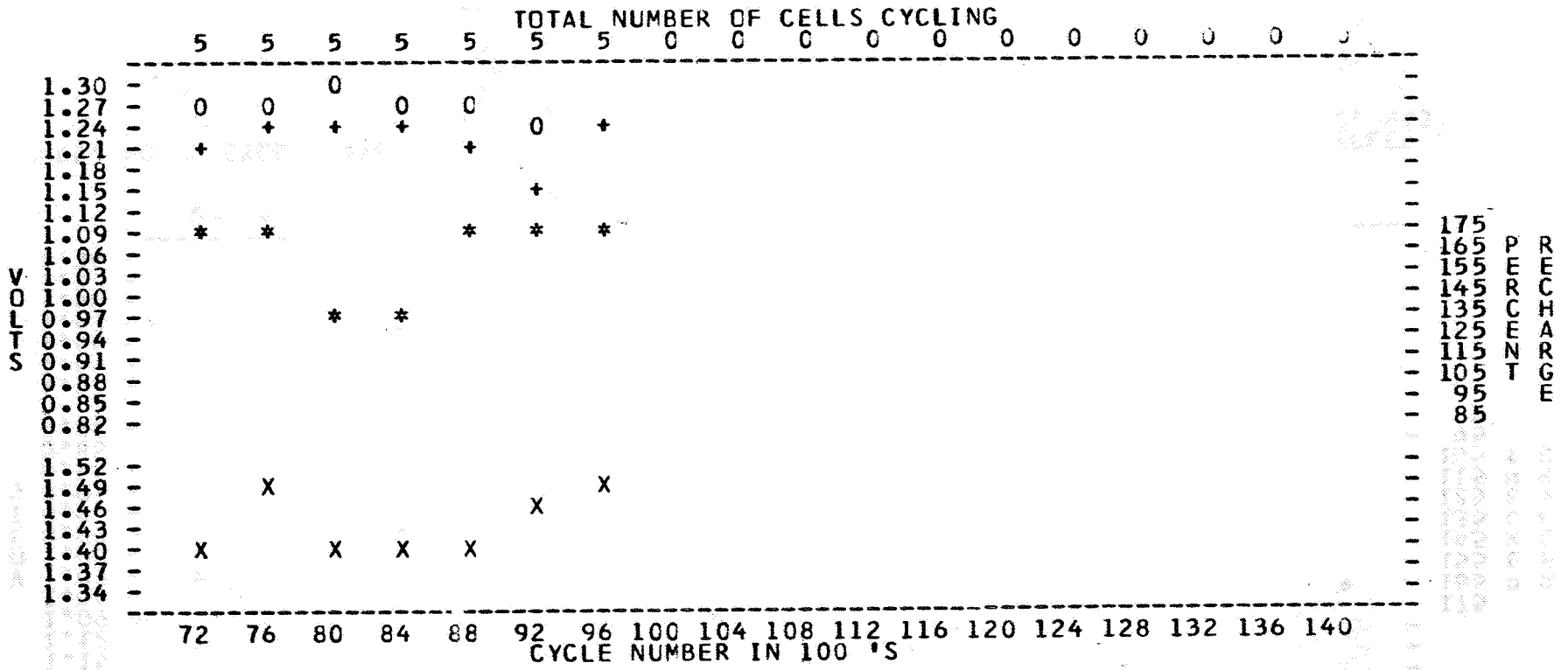
CAPACITY CHECK CYCLES
1262, 2671, 4092, 5433, 6882
8229,

STATUS CELLS CYCLING 5
CYCLES COMPLETED 9514

RESISTOR VALUES: 6.8, 6.8, 6.8, 6.8, 6.8 OHMS. TEMPERATURE CYCLING CHANGED TO 48 HOURS CYCLE 4094.

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



POS. NO. CYCLE FAILED

PACK NUMBER 060B
TYPE OF CELLS GULTON 6.00 AH
TEST TEMPERATURE 0/40 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 15 PERCENT
SPECIFIED CHARGE RATE 1.80 AMP.

CAPACITY CHECK CYCLES
1262, 2671, 4092, 5433, 6882
8229,

STATUS CELLS CYCLING 5
CYCLES COMPLETED 9514

RESISTOR VALUES: 6.8, 6.8, 6.8, 6.8, 6.8 OHMS. TEMPERATURE CYCLING CHANGED TO 48 HOURS CYCLE 4094.

FIGURE 31(C) (CONTD)

3. Gulton 10.0 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 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 of each cell in the pack to reduce the charging rate after the cells have received the desired amount of recharge. The circuit is designed to monitor the auxiliary electrode voltage of each cell while the 5-cell pack is being charged. As the auxiliary electrode voltage of any cell of the pack approaches a preset value, the circuit begins to reduce the charge current. When the auxiliary electrode voltage of any cell reaches the predetermined voltage (trip-voltage), the charge current will be reduced to a preset trickel or to zero. The charge and discharge currents are supplied by a 10-volt regulated power supply.

c. Test Parameters:

Pack Number	Test Temperature	Percent Depth of Discharge	Trip Voltage Level (Millivolts)	Resistors On Cells (Ohms) 1	2	3	4	5
20B	0° C	25	250	47	47	47	47	47
8B	25° C	25	250	47	47	47	47	47
6B	40° C	25	250	47	47	47	47	47

d. Test Results:

(1) Performance on cycling: (Figures 32(A) and 32(B).) Cycling was started in November 1967.

(a) Pack 20B: This pack failed during the pre-cycling capacity checks when the pack exploded due to the development of high internal pressure.

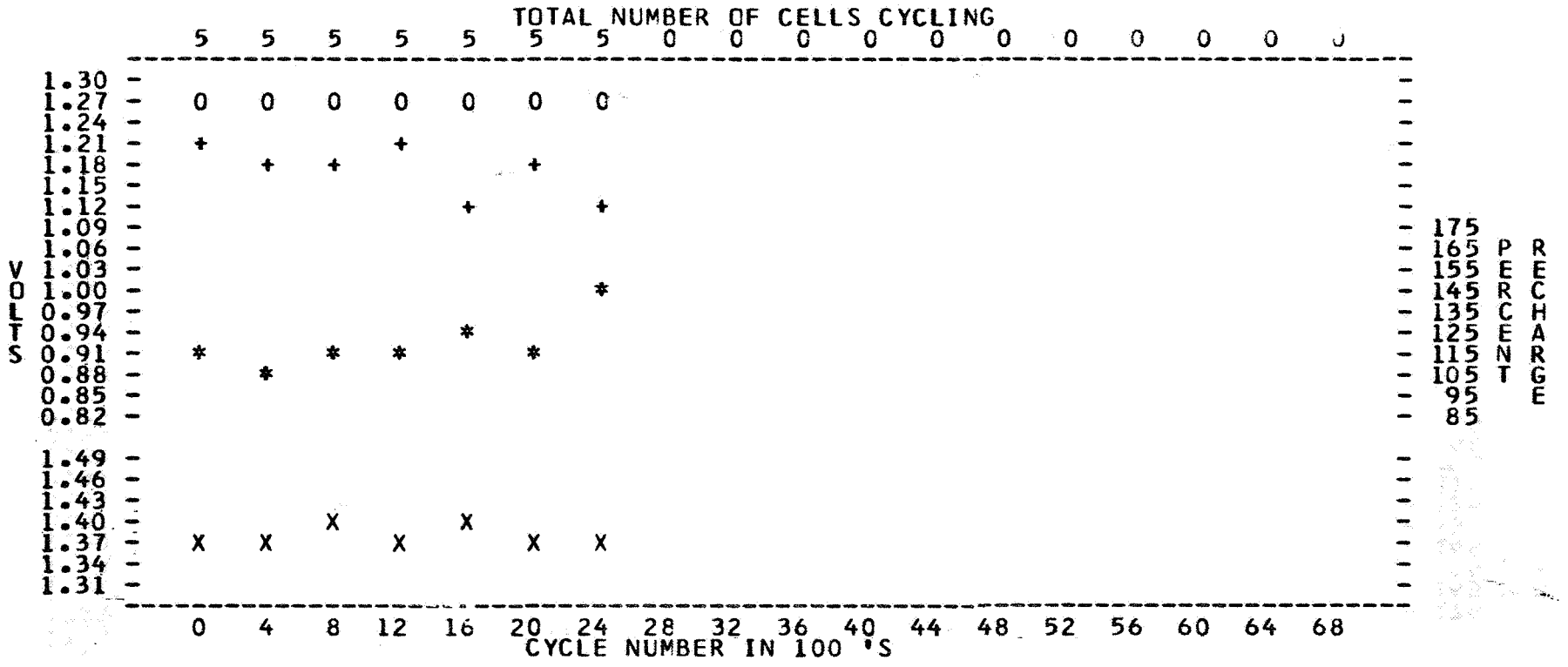
(b) Pack 8B: Following failure of two cells on cycles 2393 and 2410, cycling was discontinued following cycle 2414 due to low capacity on the three remaining cells.

(c) Pack 6B failed on cycle 602.

(d) All three packs were returned to Goddard Space Flight Center for failure analysis.

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	2393
02	2410

PACK NUMBER 008B
TYPE OF CELLS GULTON 10.00 AH
TEST TEMPERATURE 25 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 5.00 AMP.

CAPACITY CHECK CYCLES
0,

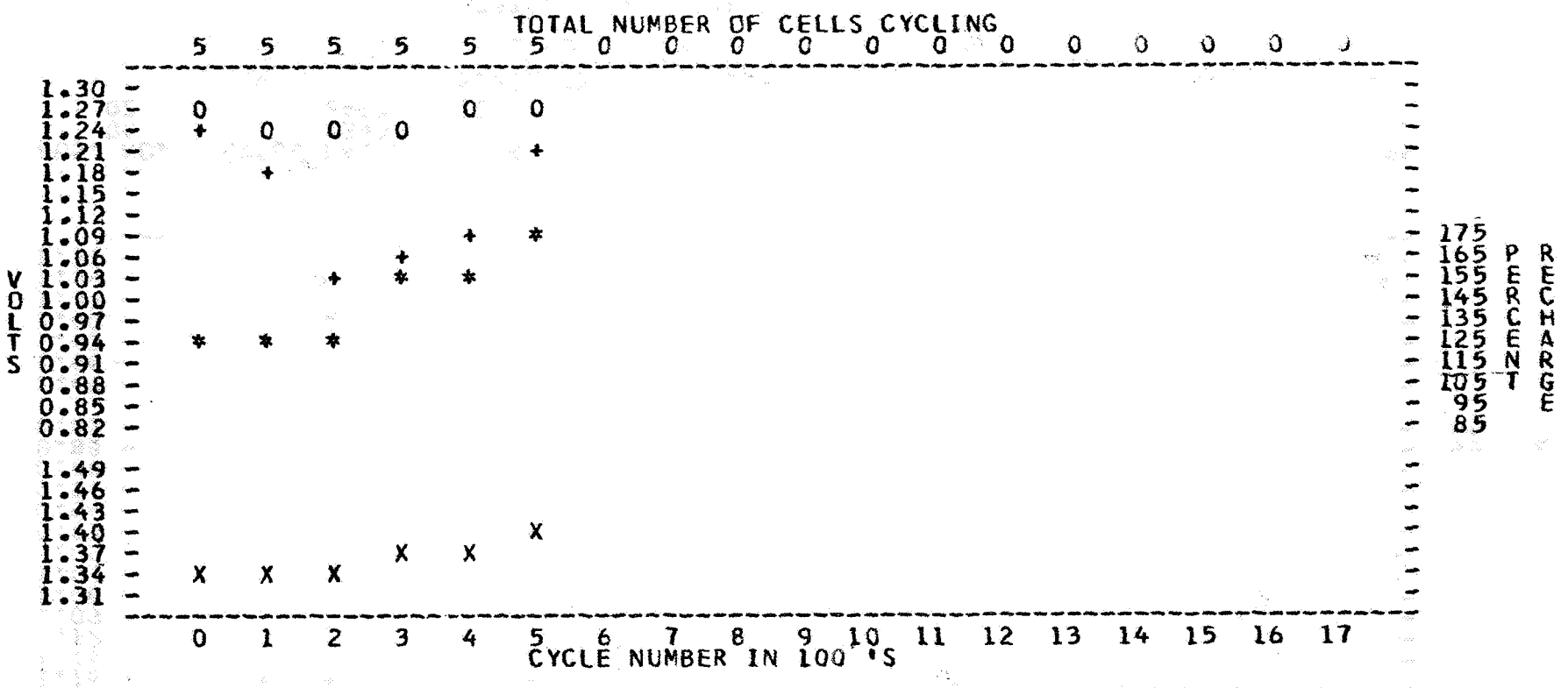
STATUS PACK FAILED
ON CYCLE NUMBER 2414

RESISTOR VALUES: 47, 47, 47, 47, 47 OHMS

FIGURE 32(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
01	602
05	602
02	602

PACK NUMBER 0068
TYPE OF CELLS GULTON 10.00 AH
TEST TEMPERATURE 40 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 5.00 AMP.

CAPACITY CHECK CYCLES
0,

STATUS PACK FAILED
ON CYCLE NUMBER 602

RESISTOR VALUES: 47, 47, 47, 47, 47 OHMS.

FIGURE 32(B)

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 of each cell in the pack to reduce the charging rate after the cells have received the desired amount of recharge. The circuit is designed to monitor the auxiliary electrode voltage of each cell while the 5-cell pack is being charged. As the auxiliary electrode voltage of any 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 currents are supplied by a unit described in Section I, Paragraph IV.B.

c. Test Parameters:

Pack Number	Test Temperature	Percent Depth of Discharge	Trip 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 33(A) through 33(D).) Cycling was started on Pack 11B in October 1966, on Packs 47B and 71B in January 1968, and on Pack 70A in February 1968. Packs 70A, 71B and 11B have completed 10,440, 10,705 and 11,858 cycles to date with one cell failure on pack 71B. Pack 47B failed on cycle 6537.

(a) Pack 71B; The one cell which failed on cycle 9991 had severe separator deterioration, migration of negative plate material, and high internal pressure as evidenced by bulging of the container.

(b) Pack 47B: The three failed cells showed severe separator deterioration, migration of negative plate material; and high pressure as evidenced by bulging of the containers of two cells and pressure release upon opening the third. Two of the cells had some leakage shown by deposits around the ceramic seals.

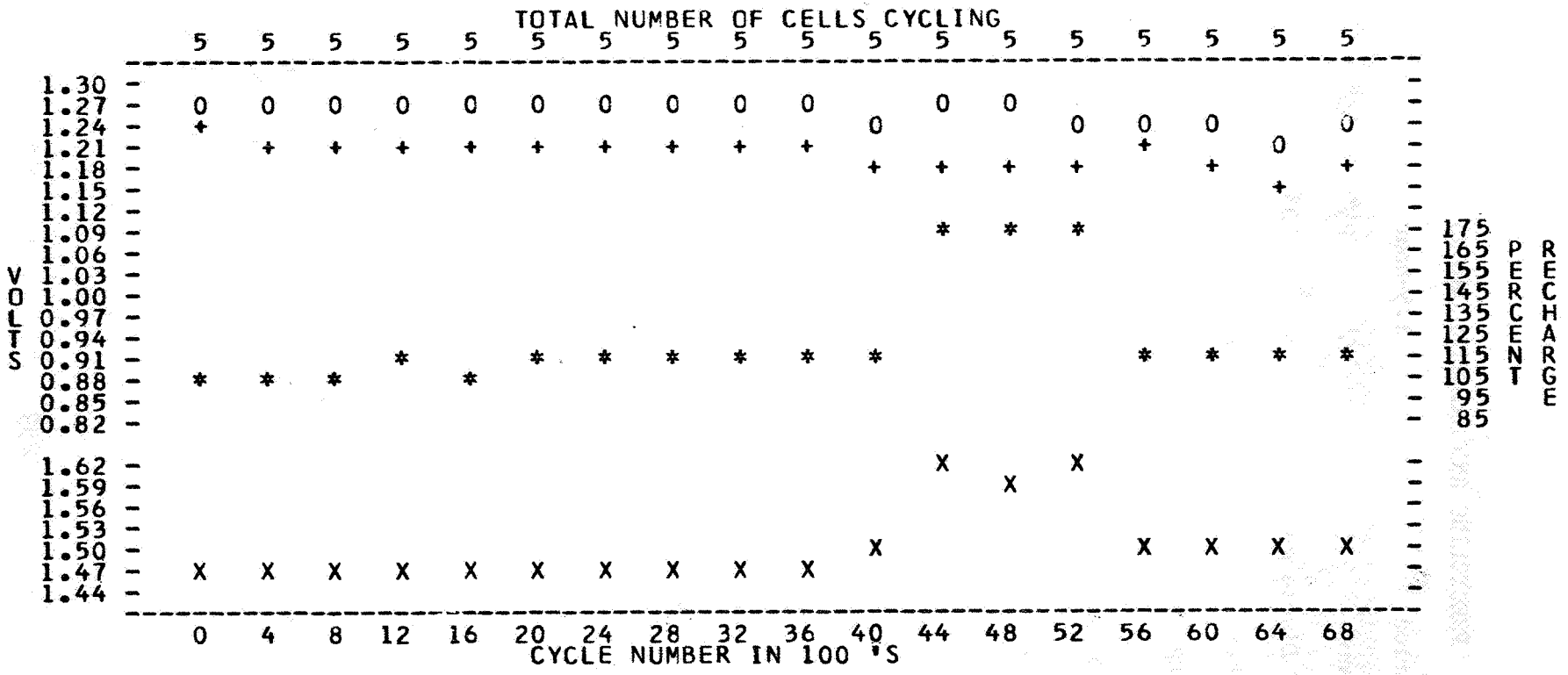
(2) Capacity checks: The ampere-hour capacities on the precycling and capacity check cycles are as follows:

PRECYCLING 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
Precycling 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	13.0	12.6	5.1	9.3
	Disch #2	9.9	13.0	7.7	5.6
440 Days	Disch #1	10.6	10.7	4.9	3.4
	Disch #2	11.6	11.5	9.0	3.4
528 Days	Disch #1	10.1	8.5	5.4	4.4
	Disch #2	10.6	10.7	7.7	6.3 F
616 Days	Disch #1	9.0	7.7	5.4	
	Disch #2	9.5	9.1	7.4	
704 Days	Disch #1		8.3	5.0	
	Disch #2		11.3	7.1	

F - 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 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.

STATUS CELLS CYCLING 5
CYCLES COMPLETED 10440

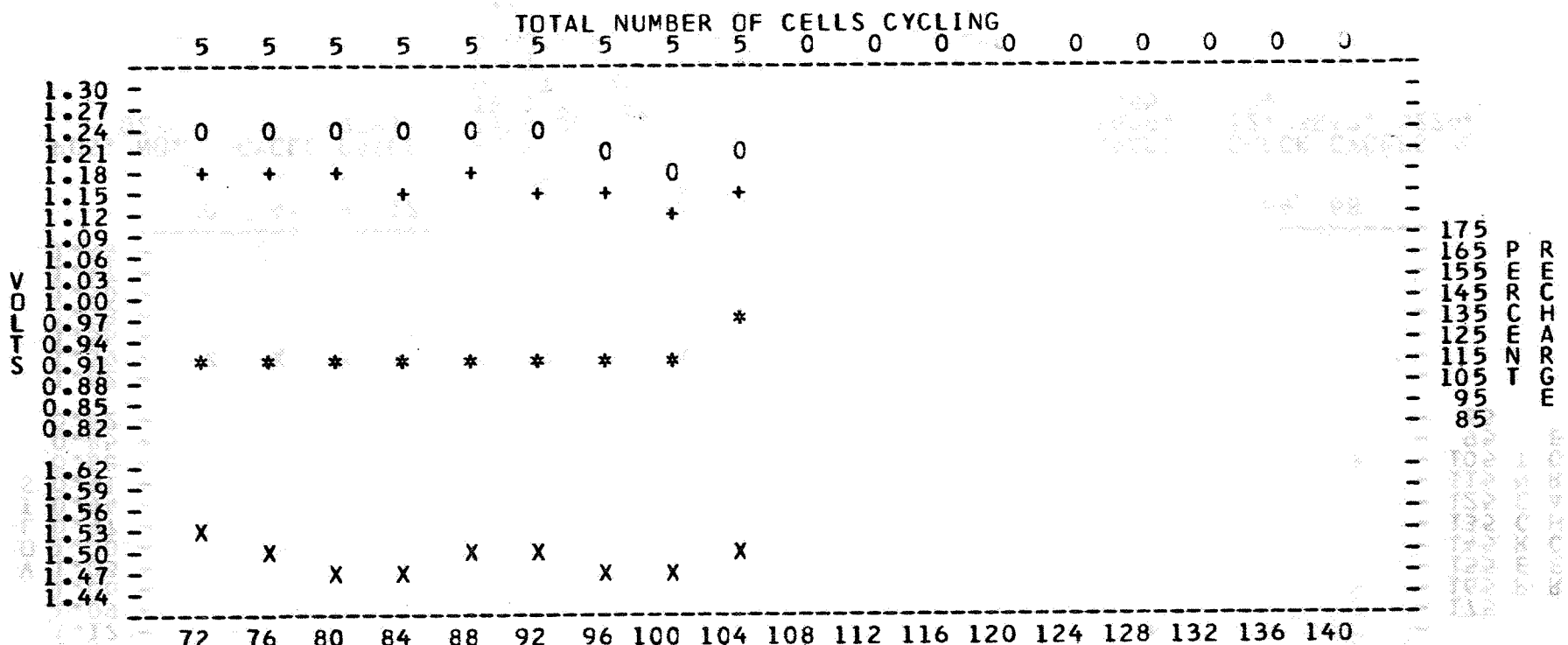
CAPACITY CHECK CYCLES
1519, 2847, 4258, 5536, 6960
8352, 9728,

RESISTOR VALUES 6.2, 6.2, 6.2, 6.2, 6.2 OHMS

FIGURE 33(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 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.

STATUS CELLS CYCLING 5
CYCLES COMPLETED 10440

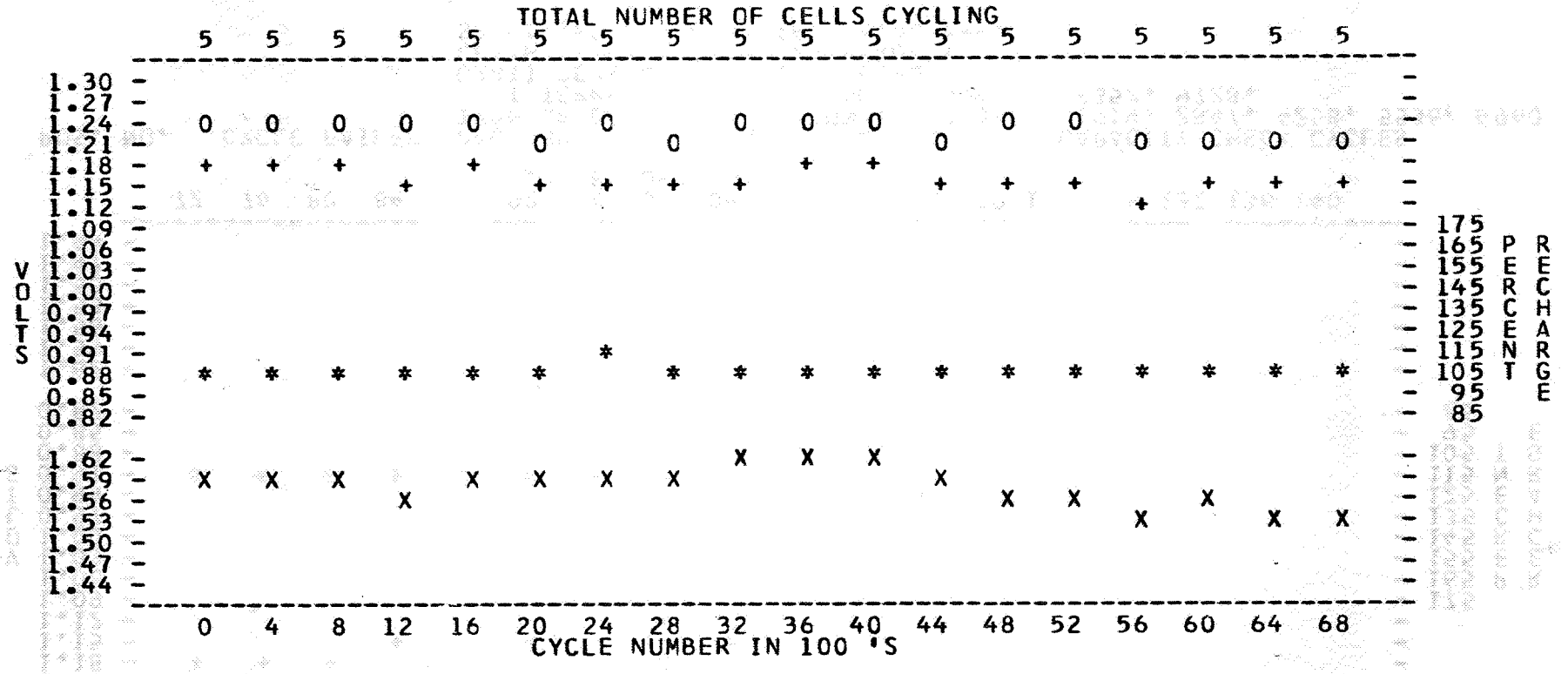
CAPACITY CHECK CYCLES
1519, 2847, 4258, 5536, 6960
8352, 9728,

RESISTOR VALUES 6.2, 6.2, 6.2, 6.2, 6.2 OHMS

FIGURE 33(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. 02
CYCLE FAILED 9991
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.

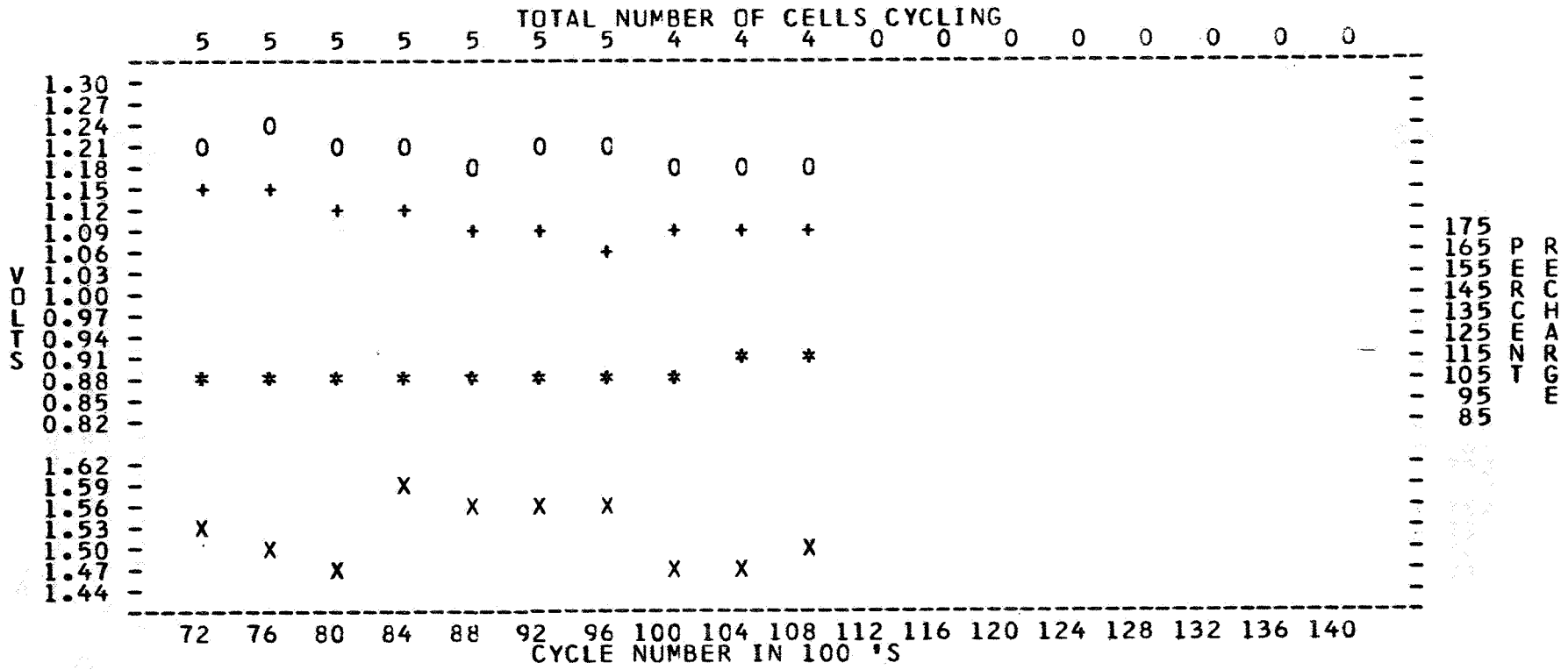
STATUS CELLS CYCLING 4
CYCLES COMPLETED 10705

CAPACITY CHECK CYCLES
1409, 1612, 3819, 5224, 6597
8085, 9300,

RESISTOR VALUES: 6.2, 6.2, 6.2, 6.2, 6.2 OHMS.

FIGURE 33(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 9991

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.

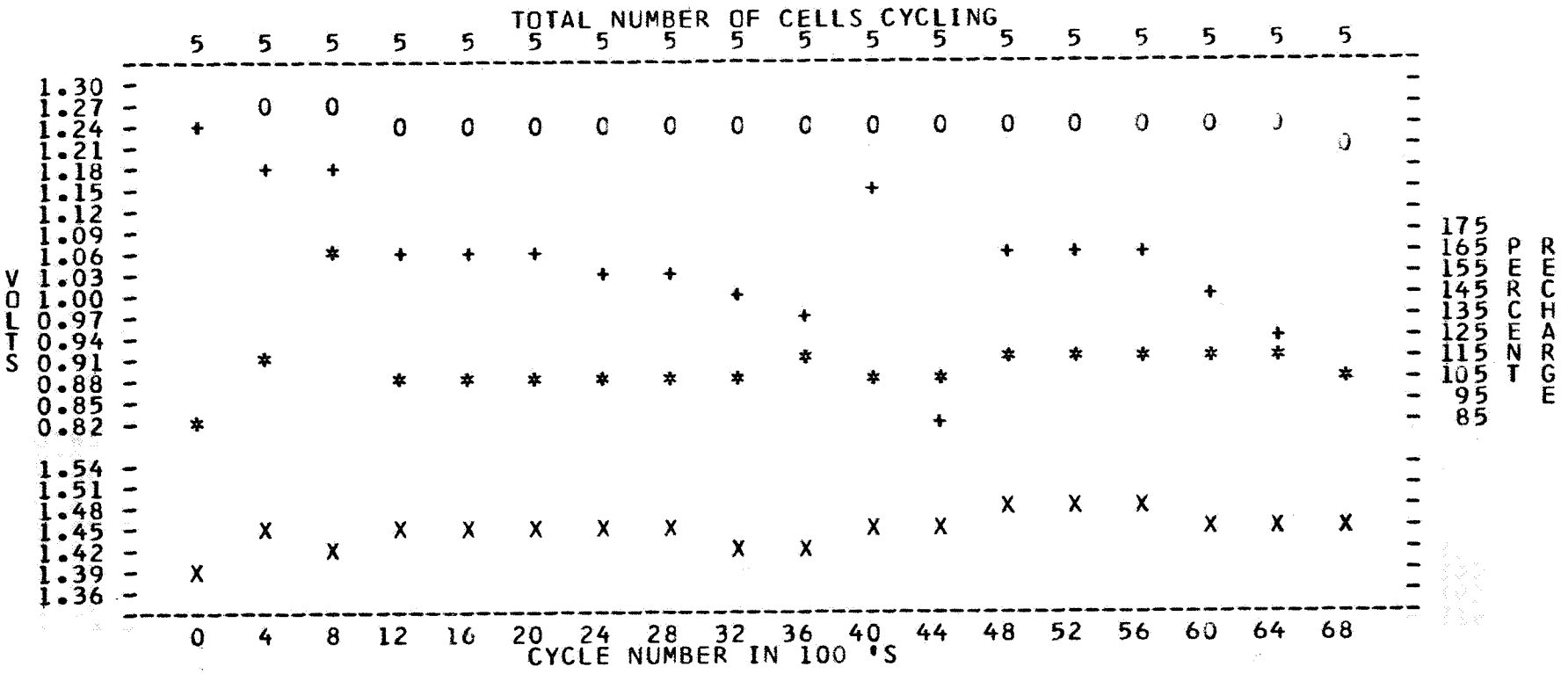
STATUS CELLS CYCLING 4
CYCLES COMPLETED 10705

CAPACITY CHECK CYCLES
1409, 1612, 3819, 5224, 6597
8085, 9300,

RESISTOR VALUES: 6.2, 6.2, 6.2, 6.2, 6.2 OHMS.

FIGURE 33(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



POS. NO. 02
CYCLE FAILED 7058

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.

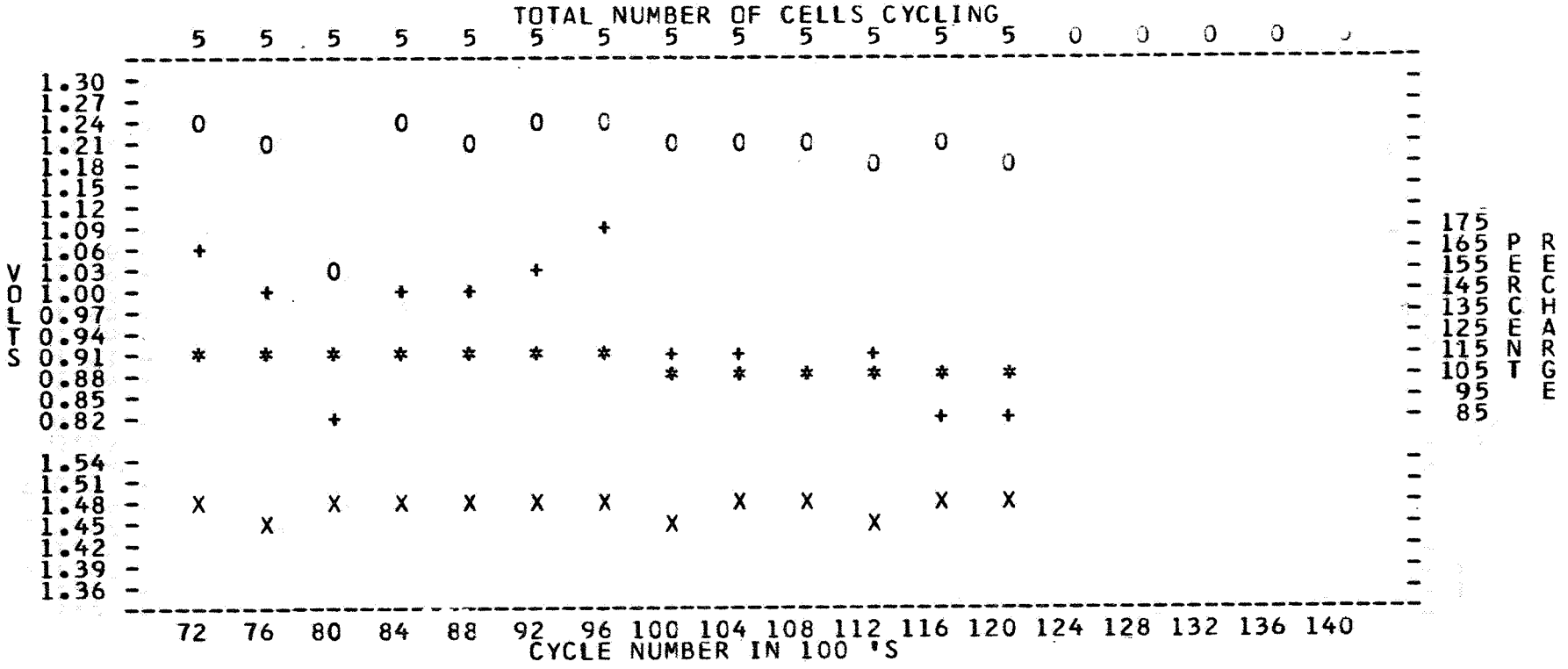
STATUS CELLS CYCLING 5
CYCLES COMPLETED 11858

CAPACITY CHECK CYCLES
370, 2180, 3906, 4002, 5631
7036, 8446, 9625, 11032,

RESISTOR VALUES: 6.2, 6.2, 6.2, 6.2, 6.2 OHMS.

FIGURE 33(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



POS. NO. 02 CYCLE FAILED 7058

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.

STATUS CELLS CYCLING 5
CYCLES COMPLETED 11858

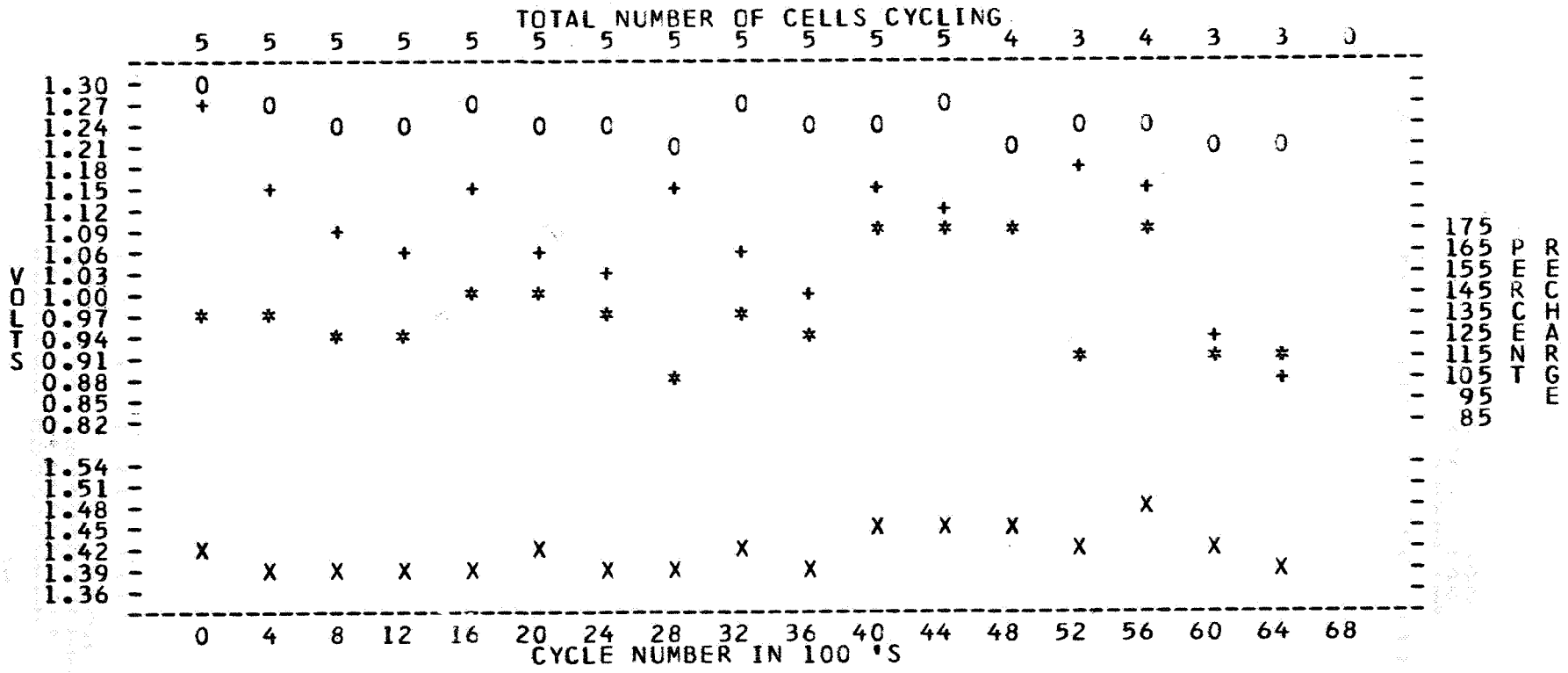
CAPACITY CHECK CYCLES
370, 2180, 3906, 4002, 5631
7036, 8446, 9625, 11032,

RESISTOR VALUES: 6.2, 6.2, 6.2, 6.2, 6.2 OHMS.

FIGURE 33(C) (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
02	5463
03	5801
01	6537

PACK NUMBER 0478
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
1428, 1602, 2815, 3878, 5382
5509,

STATUS PACK FAILED
ON CYCLE NUMBER 6537

RESISTOR VALUES: 6.2, 6.2, 6.2, 6.2, 6.2 OHMS

FIGURE 33(D)

5. Gulton 20 ah (OAO), (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. This type cell was used in the OAO satellites.

b. Test Equipment: The charge current control circuit utilizes the auxiliary electrode voltage of each cell in the pack to reduce the charging rate after the cells have received the desired amount of recharge. The circuit is designed to monitor the auxiliary electrode of each cell while the 5-cell pack is 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	Trip 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 34(A) and 34(B).) Cycling was started in March 1967. Pack 36B completed cycle 2740 on 5 September 1967 without any cell failures, at which time cycling was discontinued. Packs 58B and 12C completed 4026 and 4934 cycles respectively on 25 January 1968 without any cell failures, at which time cycling was discontinued on both packs. The three packs were returned to Goddard Space Flight Center for evaluation.

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

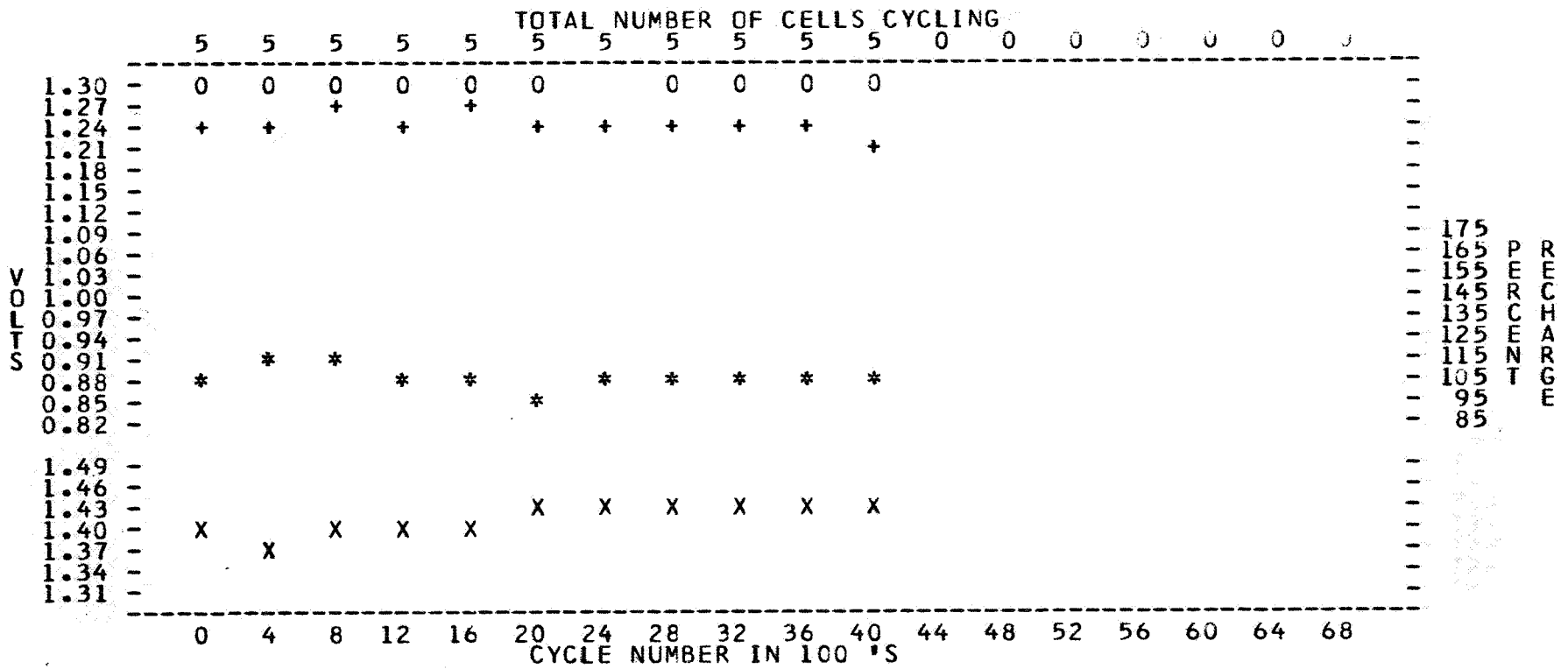
Orbit Period	1.5-hour		
Temperature	0°	25°	40°
Depth of Discharge	15%	15%	15%
Pack Number	58B	12C	36B
30 Days	*	14.7	*
88 Days	20.0	20.6	10.7 D
176 Days	22.0 D	20.5	
264 Days		22.4 D	

* Capacities were not run due to the changes in charge rate.

D - Discontinued

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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 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.

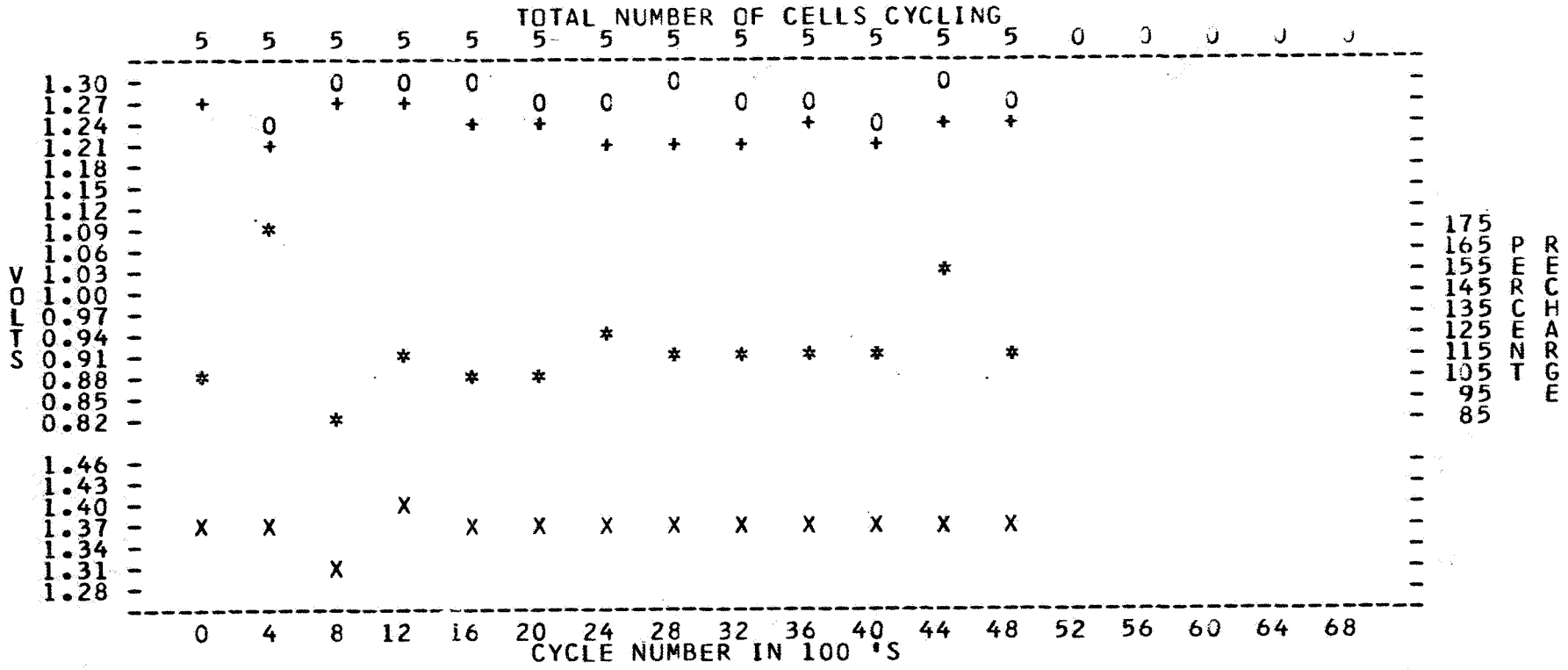
CAPACITY CHECK CYCLES
2348, 3781,

STATUS CELLS CYCLING 5
CYCLES COMPLETED 4026

RESISTOR VALUES: 6.8, 6.8, 6.8, 6.8, 6.8 OHMS DISCONTINUED TEST
RETURNED GODDARD SPACE FLIGHT CENTER FOR EVALUATION.

FIGURE 34(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 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, 4688,

STATUS CELLS CYCLING 5
CYCLES COMPLETED 4934

TEST DISCONTINUED RETURN TO GODDARD SPACE FLIGHT CENTER FOR EVALUATION
RESISTOR VALUES: 6.8, 6.8, 6.8, 6.8, 6.8 OHMS.

FIGURE 34(B)

6. Gulton 20 ah (OAO), (Nickel-Cadmium), Three 5-cell Packs, 1.5-hour Orbit Period:

a. Cell Description:

(1) Each pack consists of three conventional cells, two cells with an auxiliary electrode, and a coulometer. Both types of cells, used in OAO satellites, 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 covers.

(a) The cells with auxiliary electrode have a stainless steel tab 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 the negative terminal. These cells are the same as described in paragraph II.B.5.a.

(2) The coulometers are of the cadmium-cadmium type and are rated at 20 ampere-hours. They are of the same case construction as described in paragraph II.B.6.a.(1).

b. Test Equipment:

(1) The charge current control circuit utilizes the auxiliary voltage of either control cell in the pack to reduce the charge rate after the cells have received the desired amount of recharge. As the auxiliary electrode voltage of either control cell in the pack rises above a preset value, the charge current is reduced to zero by remotely programming a power supply.

(2) These packs are cycled with auxiliary electrode control. A coulometer on each pack is monitored to note how well the two charge control devices in the pack function.

c. Test Parameters:

Pack Number	Test Temperature	Percent Depth of Discharge	Trip Voltage Level (Millivolts)	Resistors On Cells (Ohms)
58C	*	40	250	47
36C	*	25	250	47
12D	*	15	250	47

* These cells are in an ambient temperature which varies sinusoidally from 0° to 40° C within a cycle period of 48 hours.

d. Test Results:

(1) Performance on cycling: (Figures 35(A) through 35(C).) Cycling was started in February 1968.

(a) Packs 58C and 36C failed on cycles 131 and 966 respectively. Both packs were returned to Goddard Space Flight Center for failure analysis.

(b) Pack 12D has completed 4950 cycles with no cell failures.

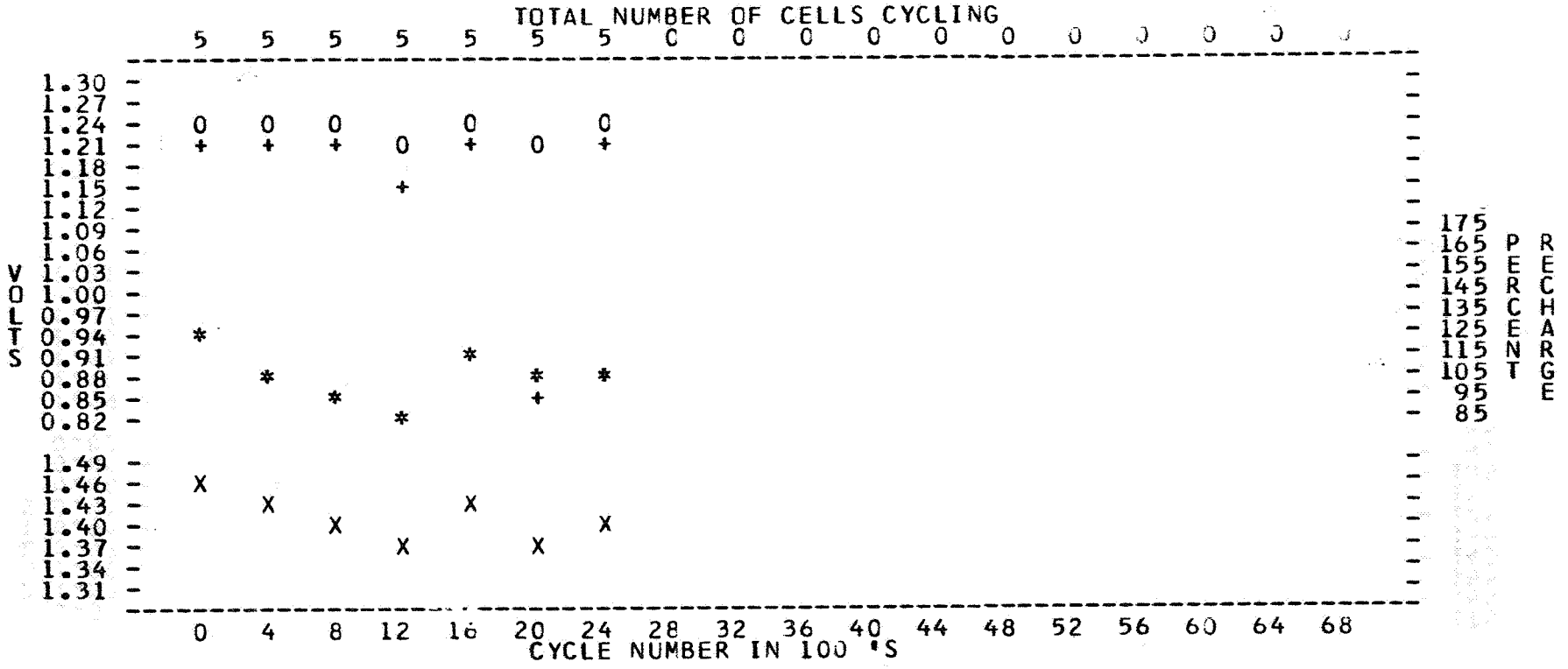
(2) Capacity checks: The ampere-hour capacities on the precycling and capacity check cycles are as follows:

Pack Number	58C	36C	12D
Precycling Capacity	22.7 F	22.9 F	25.3
88 Days			13.7
176 Days			6.3
264 Days			5.8
352 Days			5.7

The temperature cycle is stopped at 25° C for each capacity check cycle.

F - 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 058C
TYPE OF CELLS GULTON 20.00 AH
TEST TEMPERATURE 0/40 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 40 PERCENT
SPECIFIED CHARGE RATE 10.00 AMP.

CAPACITY CHECK CYCLES
0,

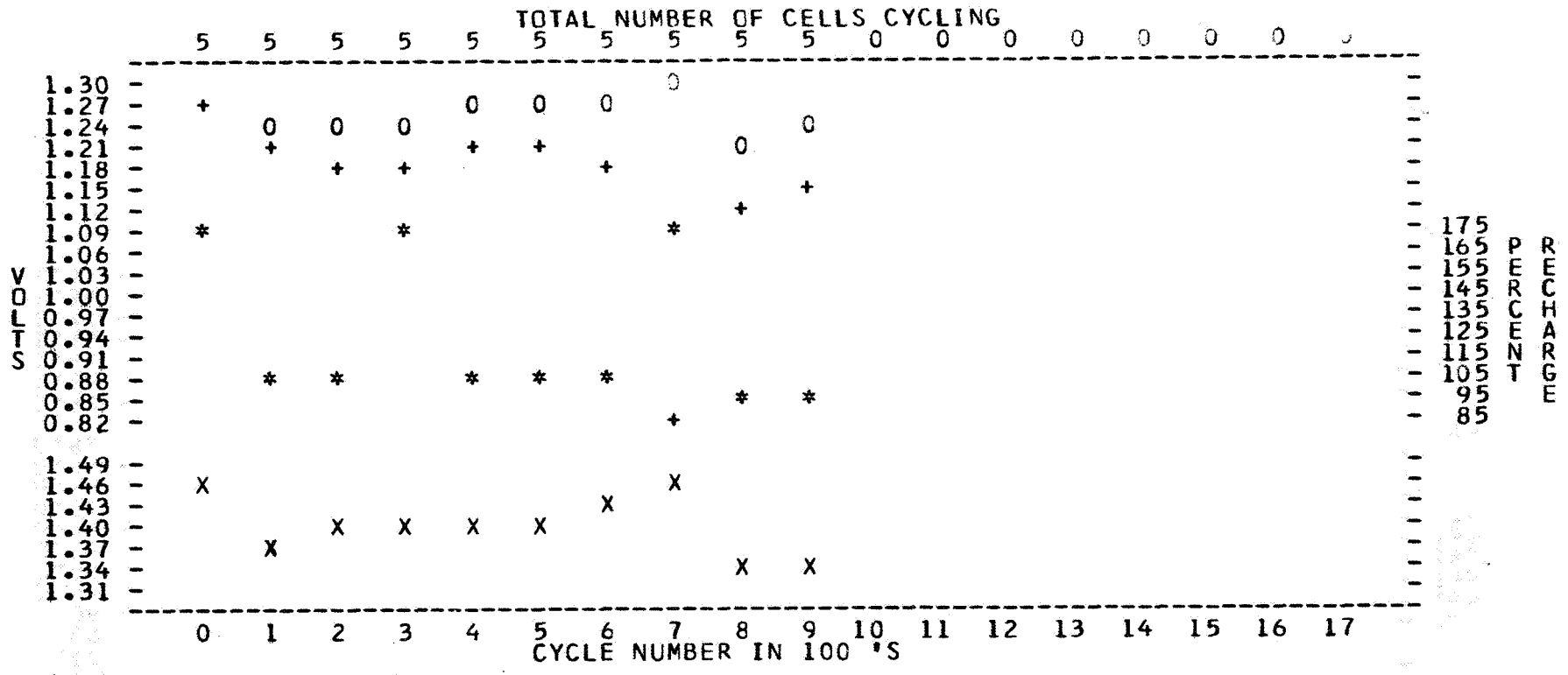
STATUS CELLS CYCLING 5
CYCLES COMPLETED 131

RESISTOR VALUES 47, 00, 00, 00, 47 OHMS.
TEMPERATURE CYCLING 0 TO 40 DEGREE WITHIN 48 HOURS

FIGURE 35(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 036C
TYPE OF CELLS GULTON 20.00 AH
TEST TEMPERATURE 0/40 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 10.00 AMP.

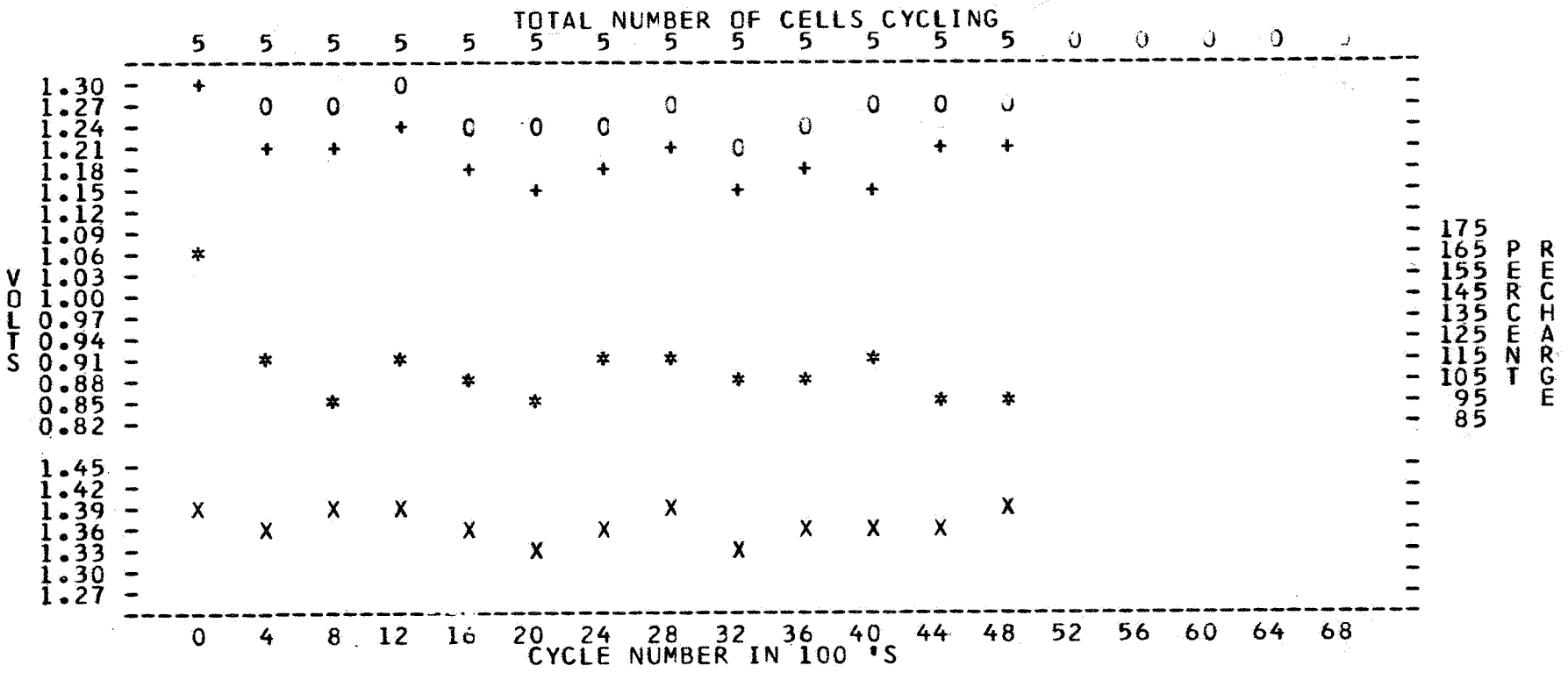
CAPACITY CHECK CYCLES
0,

STATUS CELLS CYCLING 5
CYCLES COMPLETED 966

RESISTOR VALUES: 47, 00, 00, 00, 47 OHMS TEMPERATURE CYCLING 48 HOURS DISCONTINUED

FIGURE 35(8)

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 012D
TYPE OF CELLS GULTON 20.00 AH
TEST TEMPERATURE 0/40 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE PERCENT
SPECIFIED CHARGE RATE 10.00 AMP.

CAPACITY CHECK CYCLES
871, 2318, 3665,

STATUS CELLS CYCLING 5
CYCLES COMPLETED 4950

RESISTOR VALUES: 47, 47, 00, 00, 00, OHMS

FIGURE 35(C)

7. Gulton 20 ah (OAO), (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. This type cell was used in OAO satellites.

b. Test Equipment: The shunt regulator is used to control the charge current. When the auxiliary electrode voltage of all cells is below a predetermined value charging is by constant current to a cell voltage limit (upper voltage limit). Whenever any of the auxiliary electrode voltages reaches a predetermined value (trip voltage) the voltage is automatically reduced to the lower limit. By using two voltage limit levels, the cells can receive some charge current at the beginning of charge even if the auxiliary electrode voltage is above the trip level. The charge current is supplied by a power supply.

c. Test Parameters:

Pack Number	Test Temperature	Percent Depth of Discharge	Trip Voltage Level (Millivolts)	Resistors On Cells (Ohms)	Voltage Limits Per Cell, Average Upper	Lower
54B	0° C	15	250	47	1.54	1.47
19B	25° C	15	250	47	1.45	1.38
38E	40° C	15	300	47	1.40	1.33

d. Test Results:

(1) Performance on cycling: (Figures 36(A) through 36(C).) Cycling was started in March 1968. Packs 54B, 19B and 38E have completed 4254, 4246 and 4335 cycles, respectively, with no cell failures.

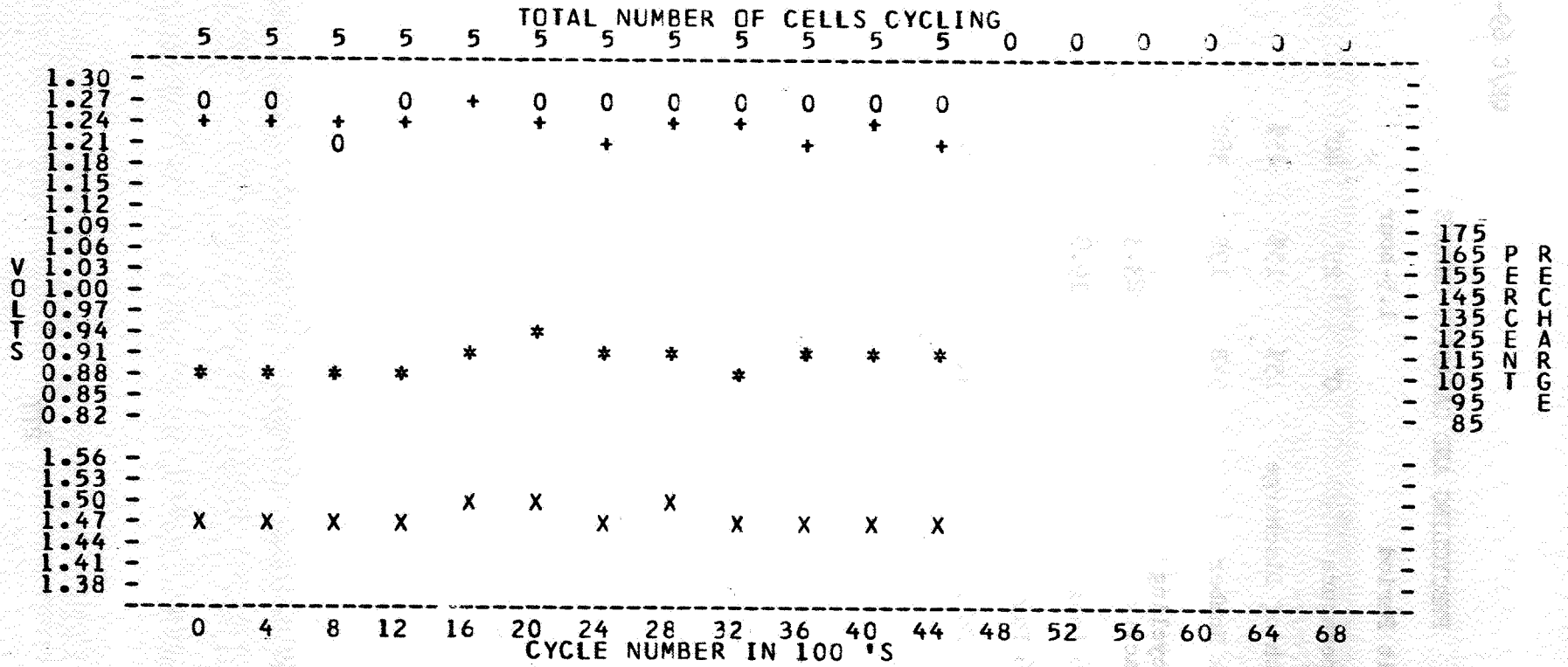
(2) Capacity checks: The ampere-hour capacities on the precycling and capacity check cycles are as follows:

PRECYCLING AND CAPACITY CHECKS

Orbit Period	1.5-hour		
Temperature	0°	25°	40°
Depth of Discharge	15%	15%	15%
Pack Number	54B	19B	38E
Precycling Capacity	22.7	23.3	17.3
88 Days	25.1	19.8	5.6
176 Days	22.7	17.3	3.7
264 Days	24.7	14.9	2.9

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 054B
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 8.00 AMP.

CAPACITY CHECK CYCLES
1397, 2835,

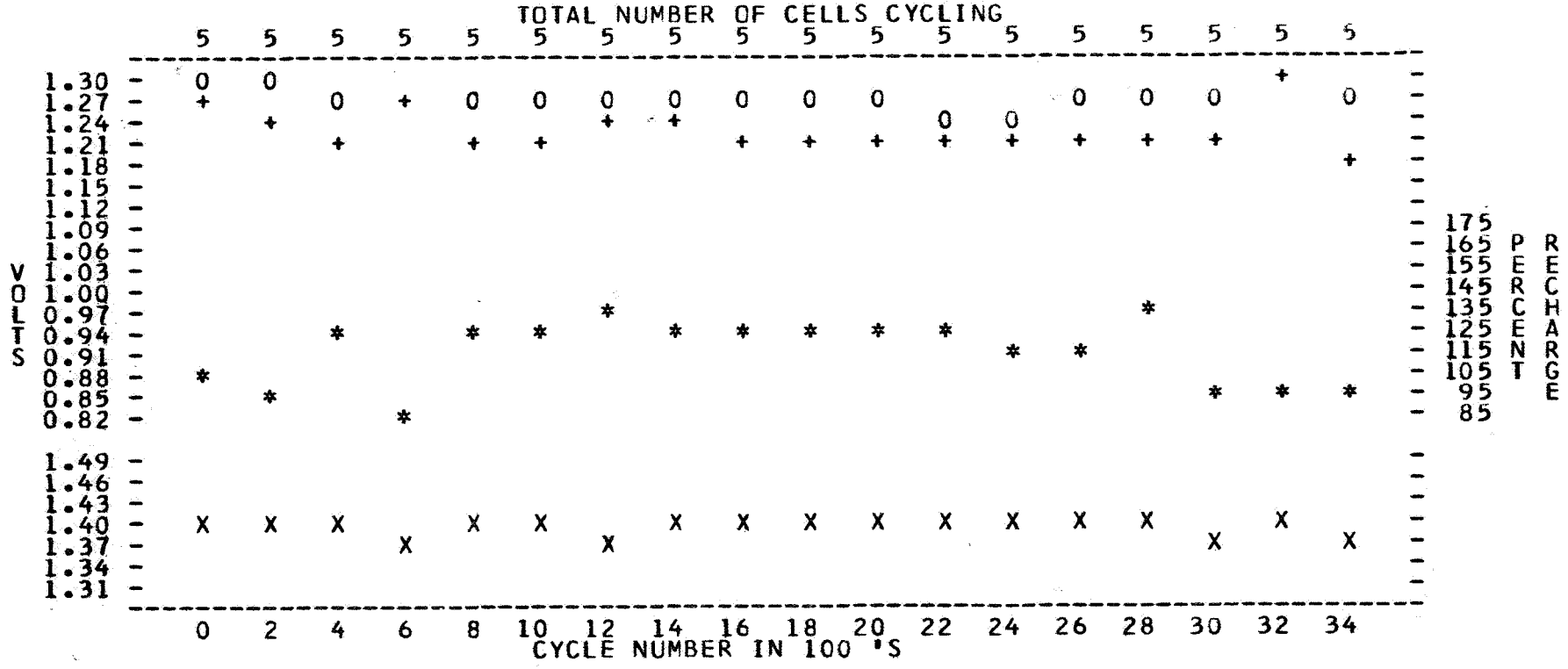
STATUS CELLS CYCLING 5
CYCLES COMPLETED 4254

RESISTOR VALUES: 0, 0, 0, 47, 47 OHMS. CYCLE 1397 VOLTAGE LIMIT 7.50 VOLTS. CYCLE 2839 CHANGED TO 250 MV.

FIGURE 36(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 019B
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 8.00 AMP.

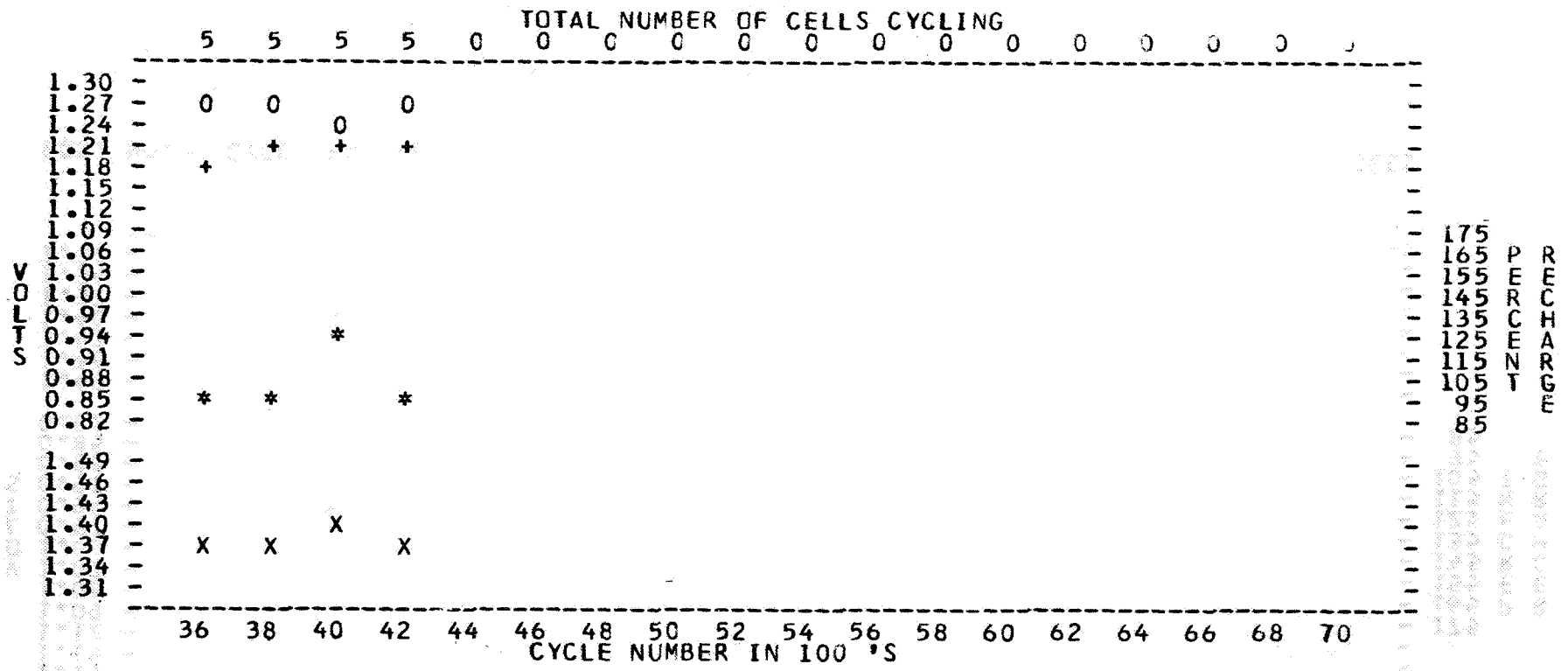
CAPACITY CHECK CYCLES
0,

STATUS CELLS CYCLING 5
CYCLES COMPLETED 4246

RESISTOR VALUES: 0, 0, 0, 47, 47 OHMS.

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



POS. NO. CYCLE FAILED

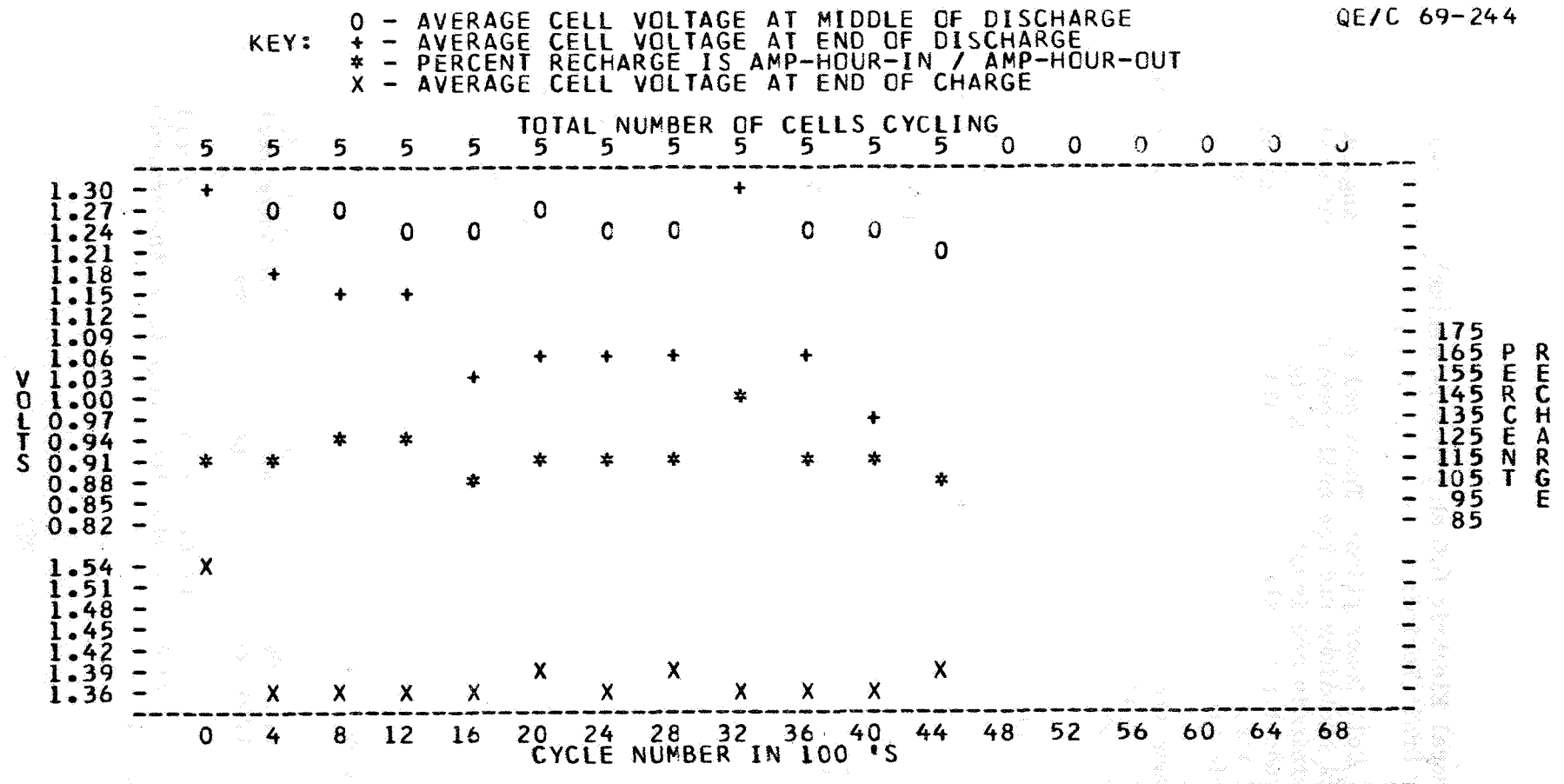
PACK NUMBER 0198
TYPE OF CELLS GULTON 20.00 AH
TEST TEMPERATURE 25 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 15 PERCENT
SPECIFIED CHARGE RATE 8.00 AMP.

CAPACITY CHECK CYCLES
0,

STATUS CELLS CYCLING 5
CYCLES COMPLETED 4246

RESISTOR VALUES: 0, 0, 0, 47, 47 OHMS.

FIGURE 36(B) (CONTD)



POS. NO. CYCLE FAILED

PACK NUMBER 038E
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 8.00 AMP.

CAPACITY CHECK CYCLES
1396, 2838, 3295,

STATUS CELLS CYCLING 5
CYCLES COMPLETED 4335

RESISTOR VALUES: 00, 00, 00, 47, 47 OHMS. CYCLE 1398 VOLTAGE LIMIT TO 6.85.CYCLE 2842 TRIP VOLTAGE 250 MV. CYCLE 3300 VOLTAGE LIMIT 6.90 VOLTS.

FIGURE 36(C)

8. General Electric 6.0 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 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 (Type C) is welded to the inner surface of the cell container. A resistor is mounted externally between the auxiliary electrode and the negative terminal. The plates of the cells of Pack 9G are separated with a material called "Chemsorb" whereas those of the cells of Pack 27C are separated with "Pellon" used as the standard for this test.

b. Test Equipment: The shunt regulator is used to control the charge current. When the auxiliary electrode voltage of all cells is below a predetermined value charging is by constant current to a cell voltage limit (upper voltage limit). Whenever any of the auxiliary electrode voltages reaches a predetermined value (trip voltage) the voltage is automatically reduced to the lower limit. By using two voltage limit levels, the cells can receive some charge current at the beginning of charge even if the auxiliary electrode voltage is above the trip level. The charge current is supplied by a power supply.

c. Test Parameters:

Pack Number	Test Temperature	Percent Depth of Discharge	Trip Voltage Level (Millivolts)	Resistors On Cells (Ohms)	Separator
9G	40° C	25	500	510	Chemsorb
27C	40° C	25	500	510	Pellon

d. Test Results:

(1) Performance on cycling: (Figures 37(A) and 37(B).) Cycling was started in November 1968.

(a) Pack 9G: This pack failed on cycle 143 at which time three cells shorted internally. In one of these cells the auxiliary electrode shorted to the positive terminal.

1. One of the failed cells was returned to Goddard Space Flight Center for detailed analysis of the separator material "Chemsorb".

2. Failure analysis of the other two cells showed that distortion of the cases and covers, caused by high internal pressure, moved the corner of the plates opposite the tabs in one cell into the bus of the plates of opposite polarity; and in the other cell the positive plates came into contact with the cell case, thereby shorting the auxiliary electrode to the positive terminal. Both cells also showed separator deterioration.

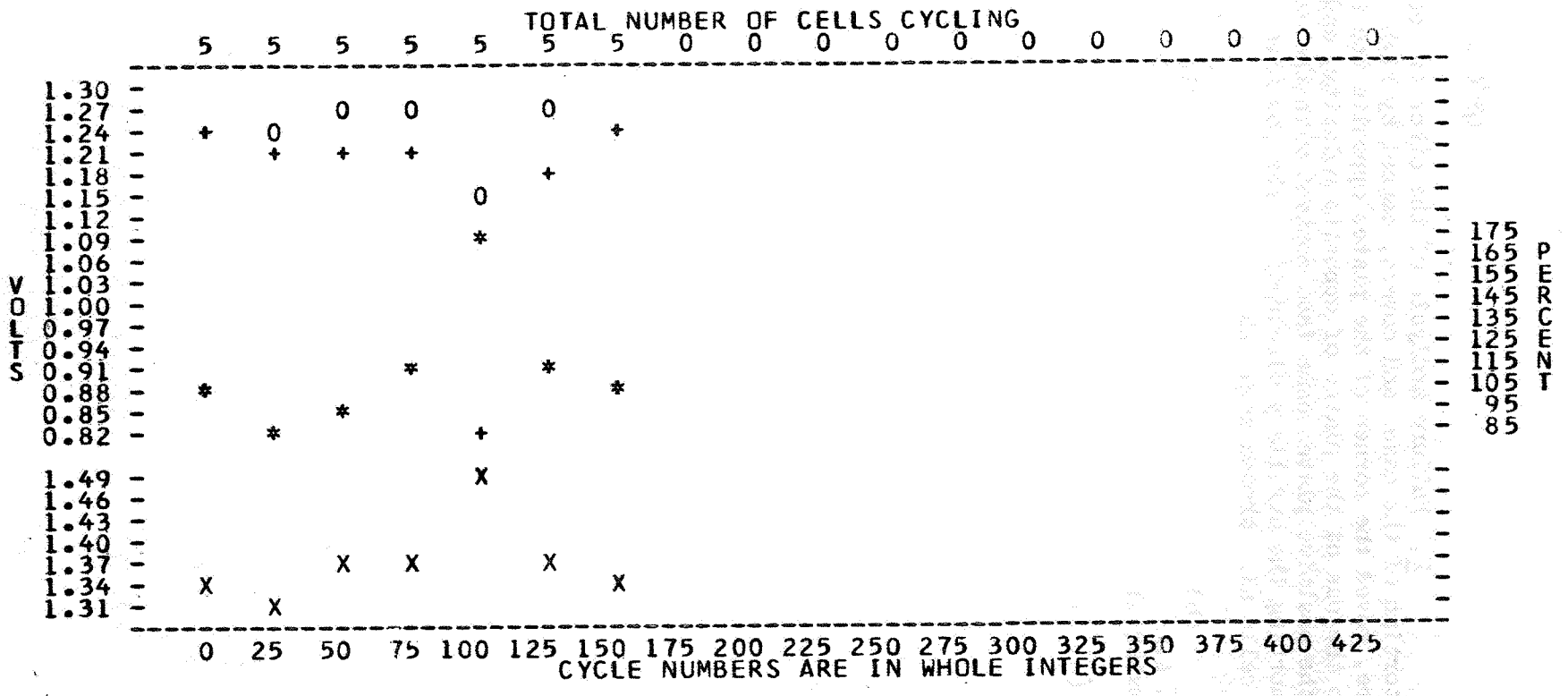
(b) Pack 27C: The two cells which failed on cycle 496 showed signs of high internal pressure and migration of negative plate material. Cycling was discontinued on cycle 559.

(2) Capacity checks:

(a) Precycling consisted of a charge at the cycling rate until the auxiliary electrode voltage of any of the five cells reached 500 millivolts followed by a discharge at the cycling rate to 1.00 volt per cell, average. Each pack delivered 3.15 ampere-hours on precycling.

(b) Capacity check cycles were to be identical to the precycling check cycle but none were made because of failure or discontinuance of cycling before first scheduled 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



POS. NO. CYCLE FAILED PACK NUMBER 009G CAPACITY CHECK CYCLES
TYPE OF CELLS GE 6.00 AH 0,
TEST TEMPERATURE 40 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 4.80 AMP.

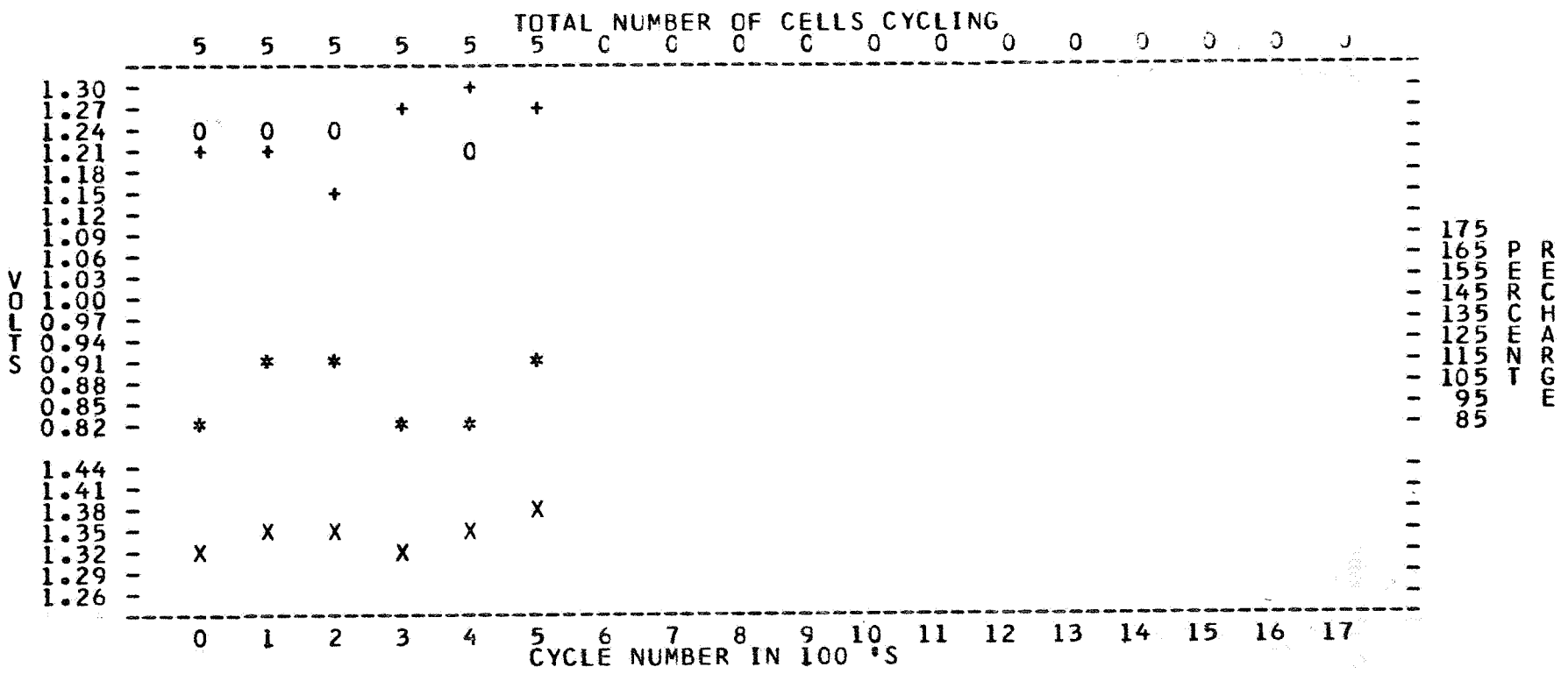
STATUS PACK FAILED
ON CYCLE NUMBER 169

RESISTOR VALUES: 510, 510, 510, 510, 510 OHMS

FIGURE 37(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 027C
TYPE OF CELLS GE 6.00 AH
TEST TEMPERATURE 40 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 4.80 AMP.

CAPACITY CHECK CYCLES
0,

STATUS CELLS CYCLING 5
CYCLES COMPLETED 554

RESISTOR VALUES: 510, 510, 510, 510, 510 OHMS. DISCONTINUED BY GODDARD SPACE FLIGHT CENTER.

FIGURE 37(B)

9. General Electric 6.0 ah (Nickel-Cadmium), Eight 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. The cells of four packs contain Type C auxiliary electrode, which is a sintered nickel plaque with a Teflon coating; whereas those of the other four packs contain Type B auxiliary electrode, which is a platinum loaded sintered nickel plaque with no Teflon coating.

b. Test Equipment: The charge current control circuit utilizes the auxiliary electrode voltage of each cell in the pack to reduce the charge rate after the cells have received the desired amount of recharge. The circuit is designed to monitor the auxiliary electrode voltage of each cell while the 5-cell pack is being charged. As the auxiliary electrode voltage of any cell of the pack approaches a preset value, the circuit begins to reduce the charge current. When the auxiliary electrode voltage of any cell reaches the predetermined voltage (trip voltage), the charge current is reduced to a preset trickle or to zero. The charge and discharge currents are supplied by a power supply.

c. Test Parameters:

Pack Number	Test Temperature	Percent Depth of Discharge	Trip Voltage Level (Millivolts)	Resistors On Cells (Ohms)	Type of Auxiliary Electrode
52C	0° C	25	250	82	C
50B	0° C	25	250	82	B
5B	25° C	25	250	82	C
17B	25° C	25	250	82	B
6C	40° C	25	250	82	C
42C	40° C	25	250	82	B
62B	*	25	250	82	C
65B	*	25	250	82	B

* These cells are in an ambient temperature which varies sinusoidally from 0° to 40° C within a cycle period of 48 hours.

d. Test Results:

(1) Performance on cycling: (Figures 38(A) through 38(H).) Cycling was started in June 1968. These packs have completed from 2423 to 3290 cycles with no cell failures.

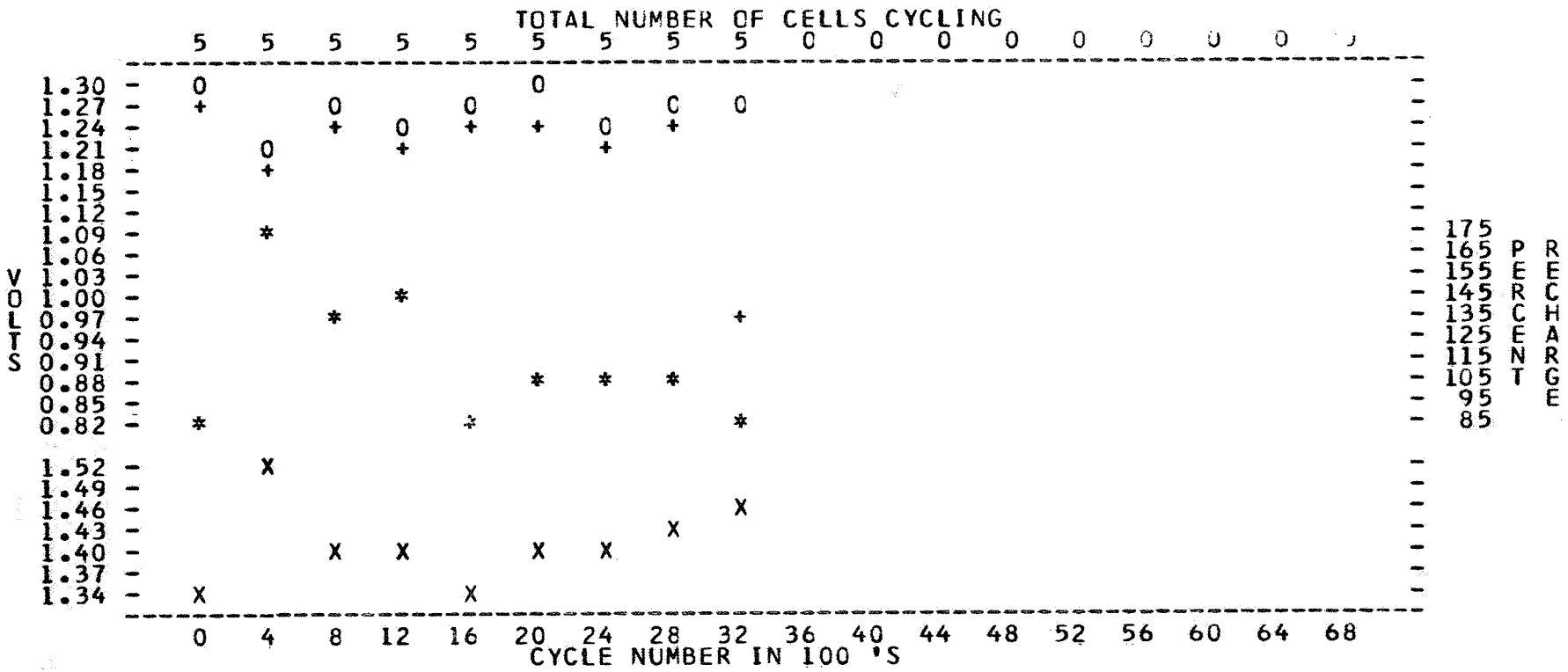
(2) Capacity checks: The ampere-hour capacities on the precycling and capacity check cycles are as follows:

PRECYCLING AND CAPACITY CHECKS

Orbit Period	1.5-hour							
Temperature	0°	0°	25°	25°	40°	40°	*	*
Depth of Discharge	25%	25%	25%	25%	25%	25%	25%	25%
Pack Number	52C	50B	5B	17B	6C	42C	62B	65B
Auxiliary Electrode	C	B	C	B	C	B	C	B
Precycling Capacity	7.05	7.20	7.50	7.38	5.55	5.10	7.40	7.70
88 Days	6.50	7.40	3.20	4.70	1.50	1.50	1.15	5.80
176 Days	4.85	7.30	1.85	3.20	1.55	1.75		5.75

* These cells are in an ambient temperature which varies sinusoidally from 0° to 40° C within a cycle period of 48 hours. The temperature cycle is stopped at 25° C for each capacity check cycle.

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 052C
TYPE OF CELLS GE 6.00 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 3.00 AMP.

CAPACITY CHECK CYCLES
1335, 2758,

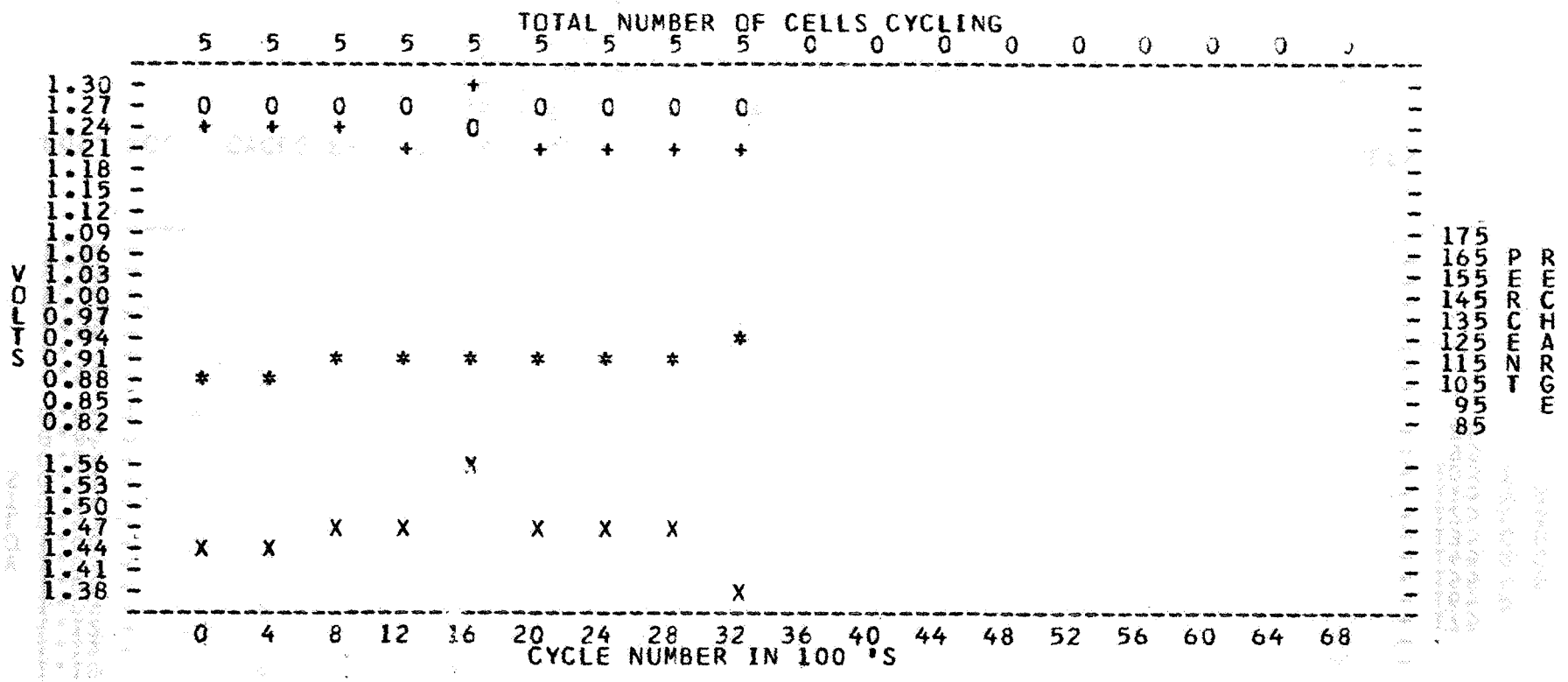
STATUS CELLS CYCLING 5
CYCLES COMPLETED 3040

RESISTOR VALUES: 82, 82, 82, 82, 82 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

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POS. NO. CYCLE FAILED

PACK NUMBER 050B
TYPE OF CELLS GE 6.00 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 3.00 AMP.

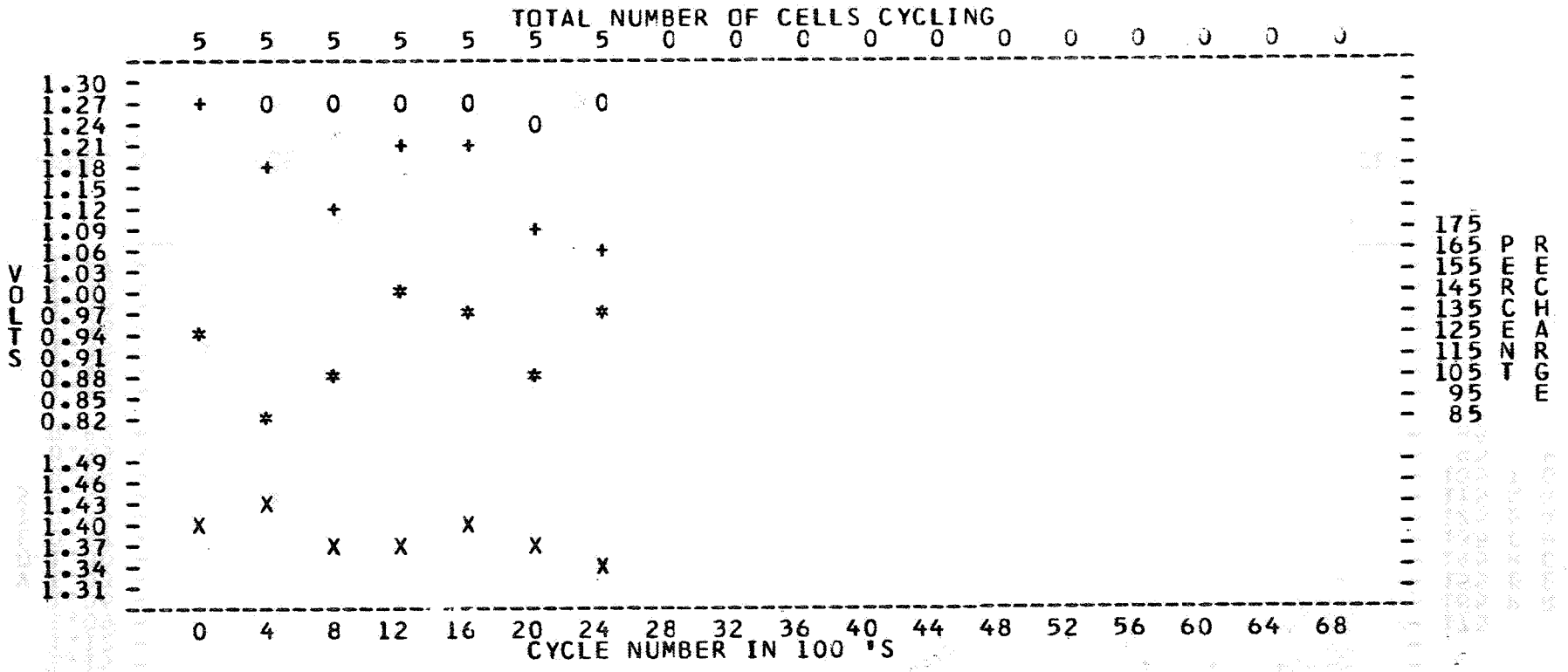
CAPACITY CHECK CYCLES
1441, 2867,

STATUS CELLS CYCLING 5
CYCLES COMPLETED 3276

RESISTOR VALUES: 82, 82, 82, 82, 82 OHMS.

FIGURE 38(8)

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 005B
TYPE OF CELLS GE 6.00 AH
TEST TEMPERATURE 25 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 3.00 AMP.

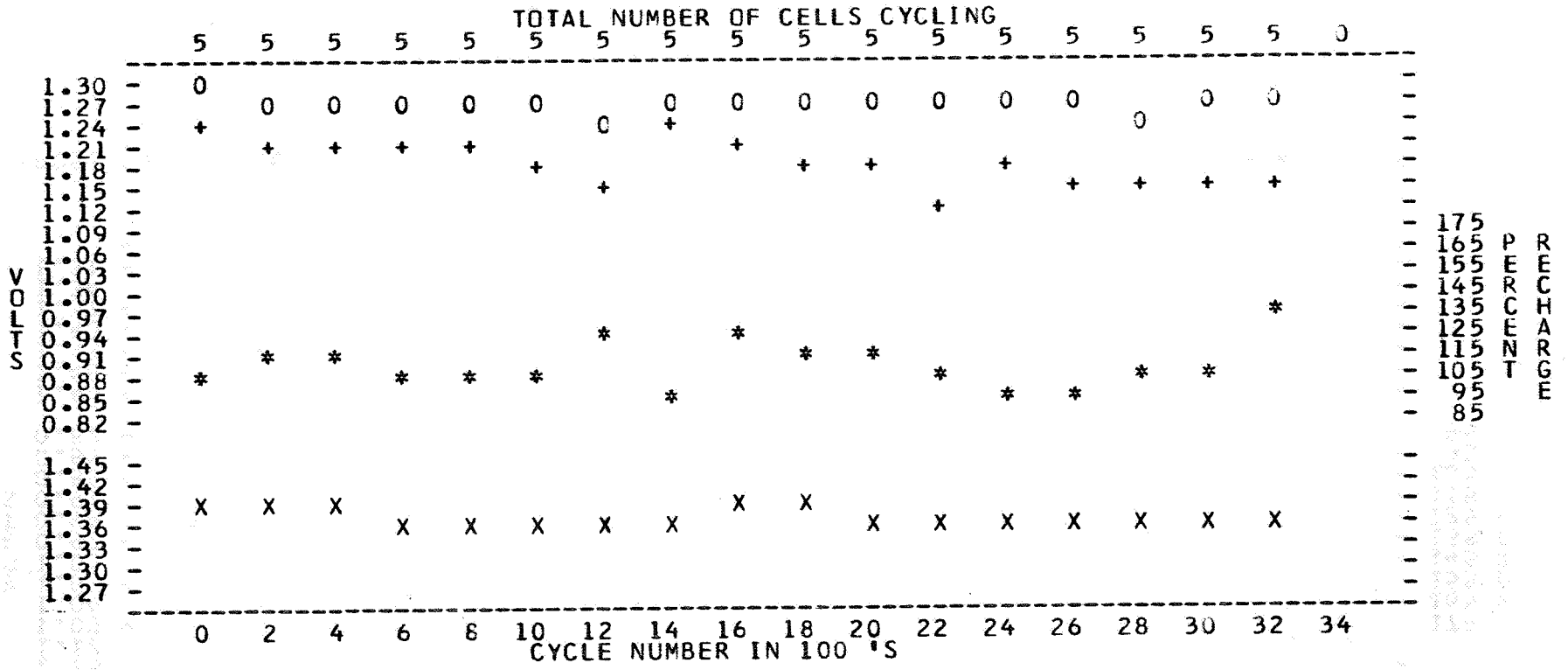
CAPACITY CHECK CYCLES
1385, 2101,

STATUS CELLS CYCLING 5
CYCLES COMPLETED 2529

RESISTOR VALUES: 82, 82, 82, 82, 82 OHMS. TRIP VOLTAGE CHANGED 350 MV CYCLE 495. TRIP VOLTAGE CHANGED TO 360 MV CYCLE 1521. RESISTOR CHANGED TO 40 OHMS EACH CELL.

FIGURE 38(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



POS. NO. CYCLE FAILED

PACK NUMBER 017B
TYPE OF CELLS GE 6.00 AH
TEST TEMPERATURE 25 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 3.00 AMP.

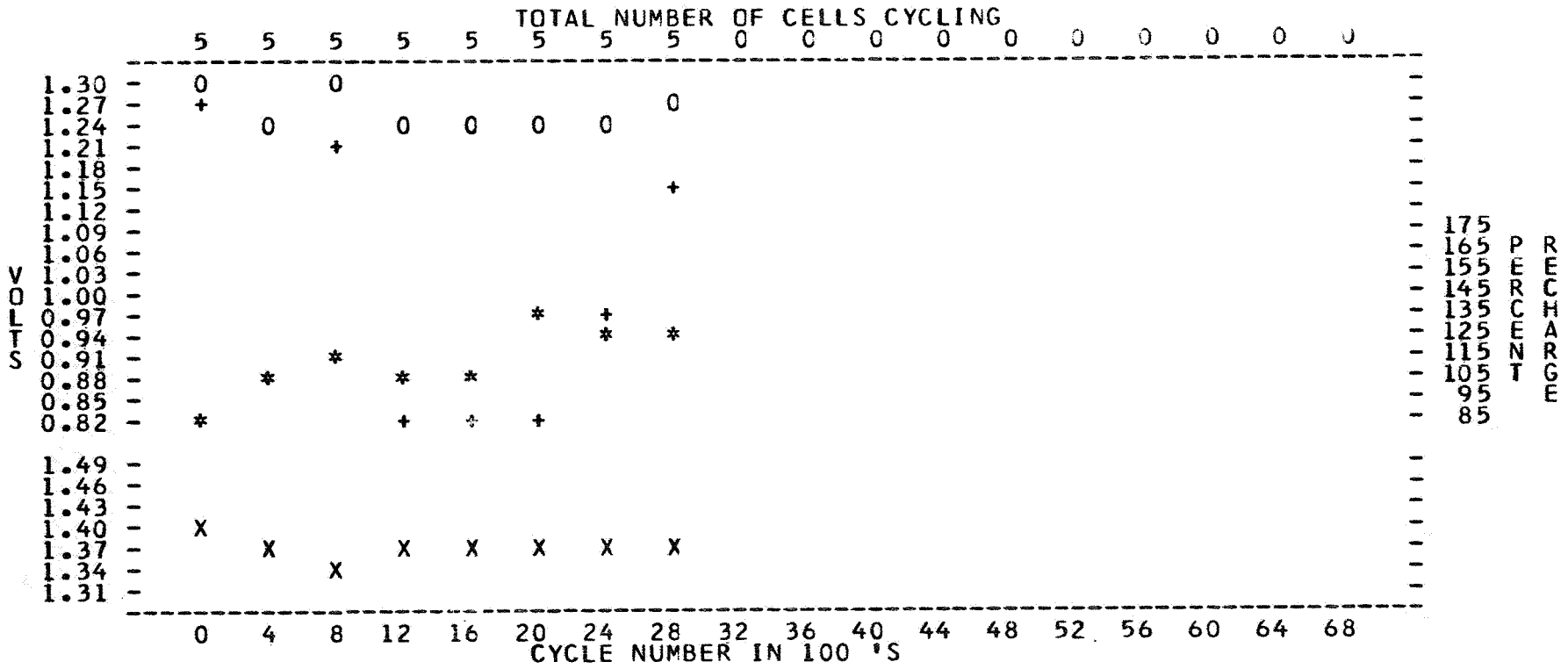
CAPACITY CHECK CYCLES
1422, 2862,

STATUS CELLS CYCLING 5
CYCLES COMPLETED 3290

RESISTOR VALUES: 82, 82, 82, 82, 82 OHMS.

FIGURE 38(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 006C
TYPE OF CELLS GE 6.00 AH
TEST TEMPERATURE 40 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 3.00 AMP.

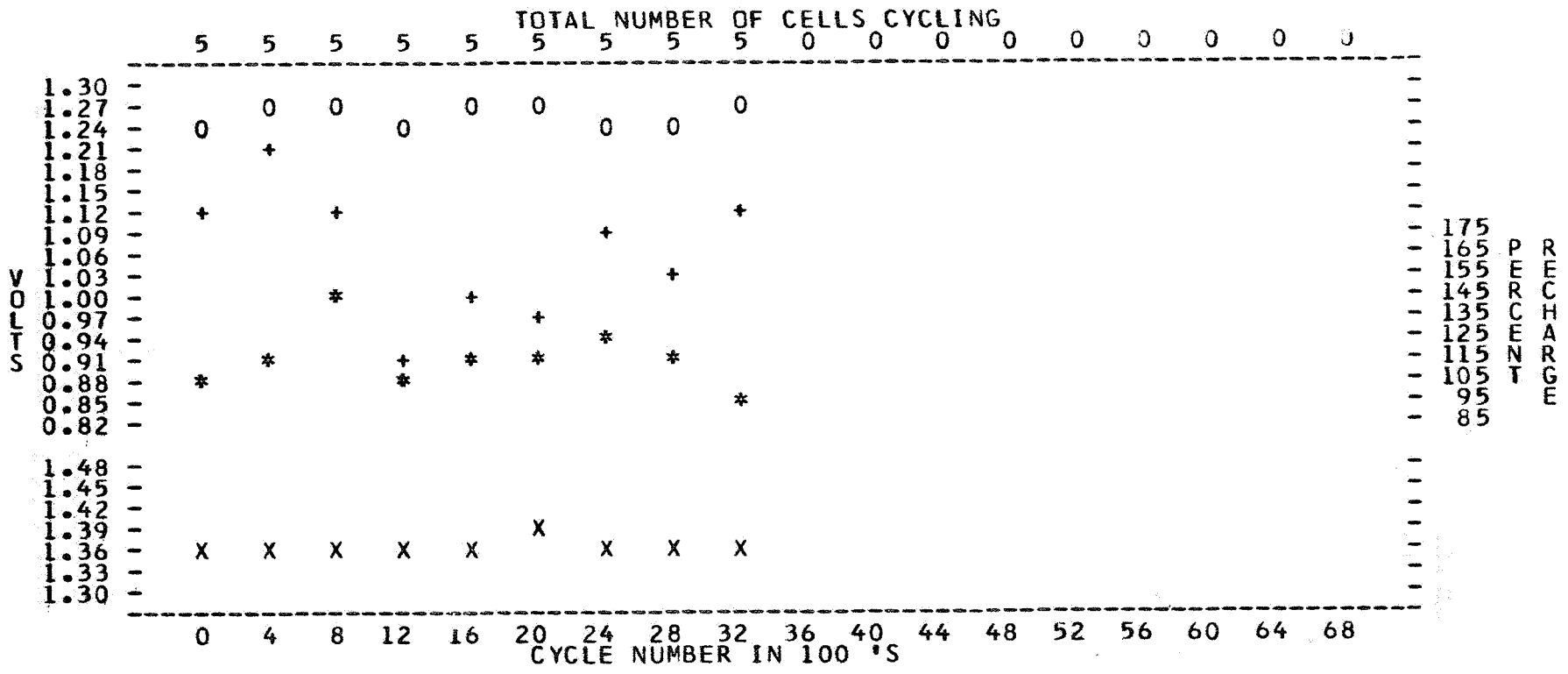
CAPACITY CHECK CYCLES
1295, 2716,

STATUS CELLS CYCLING 5
CYCLES COMPLETED 2998

RESISTOR VALUES: 82, 82, 82, 82, 82 OHMS. TRIP VOLTAGE CHANGED 350 MV CYCLE 282. TRIP VOLTAGE CHANGED TO 450 MV CYCLE 626.

FIGURE 38(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



POS. NO. CYCLE FAILED

PACK NUMBER 042C
TYPE OF CELLS GE 6.00 AH
TEST TEMPERATURE 40 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 3.00 AMP.

STATUS CELLS CYCLING 5
CYCLES COMPLETED 3273

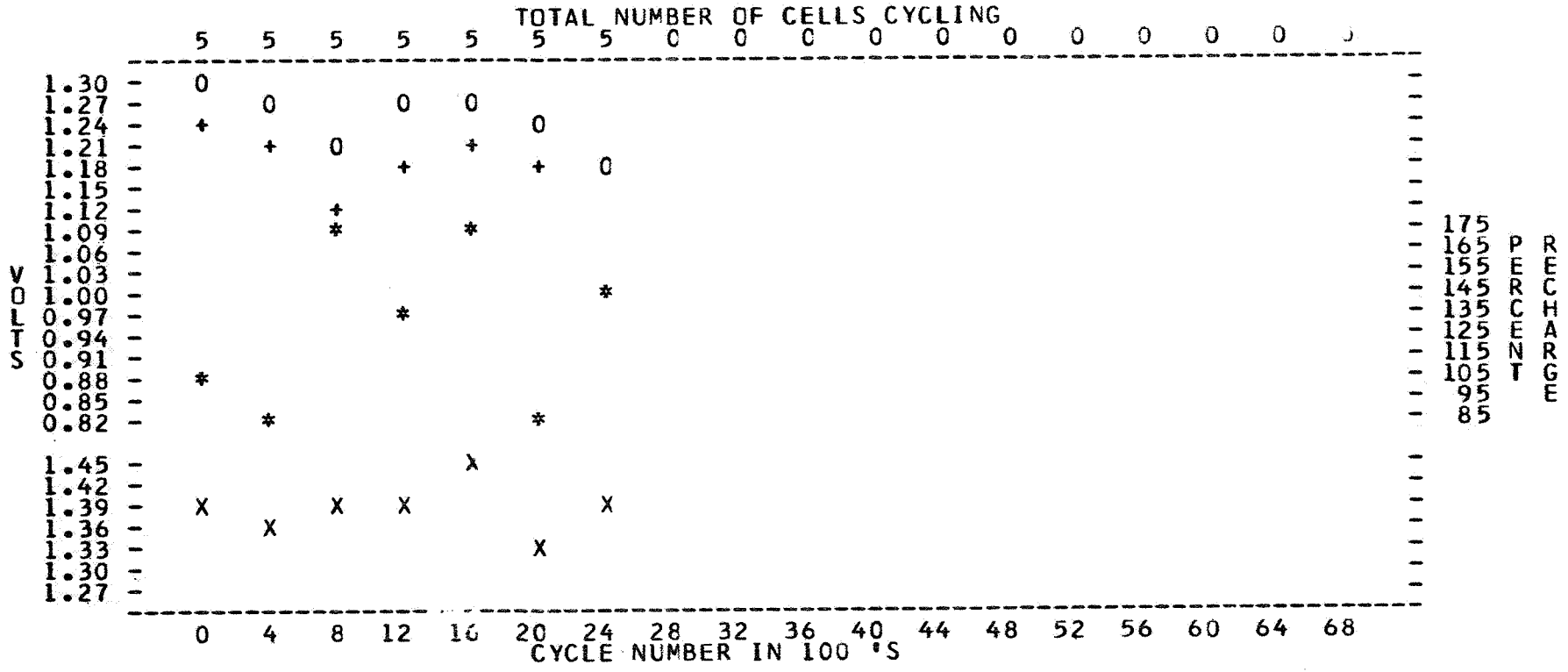
CAPACITY CHECK CYCLES
1443, 2866,

TRIP VOLTAGE CHANGED 450 MV CYCLE 753.
RESISTOR VALUES: 82, 82, 82, 82, 82 OHMS

FIGURE 38(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

PACK NUMBER 062B
TYPE OF CELLS GE 6.00 AH
TEST TEMPERATURE 0/40 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 3.00 AMP.

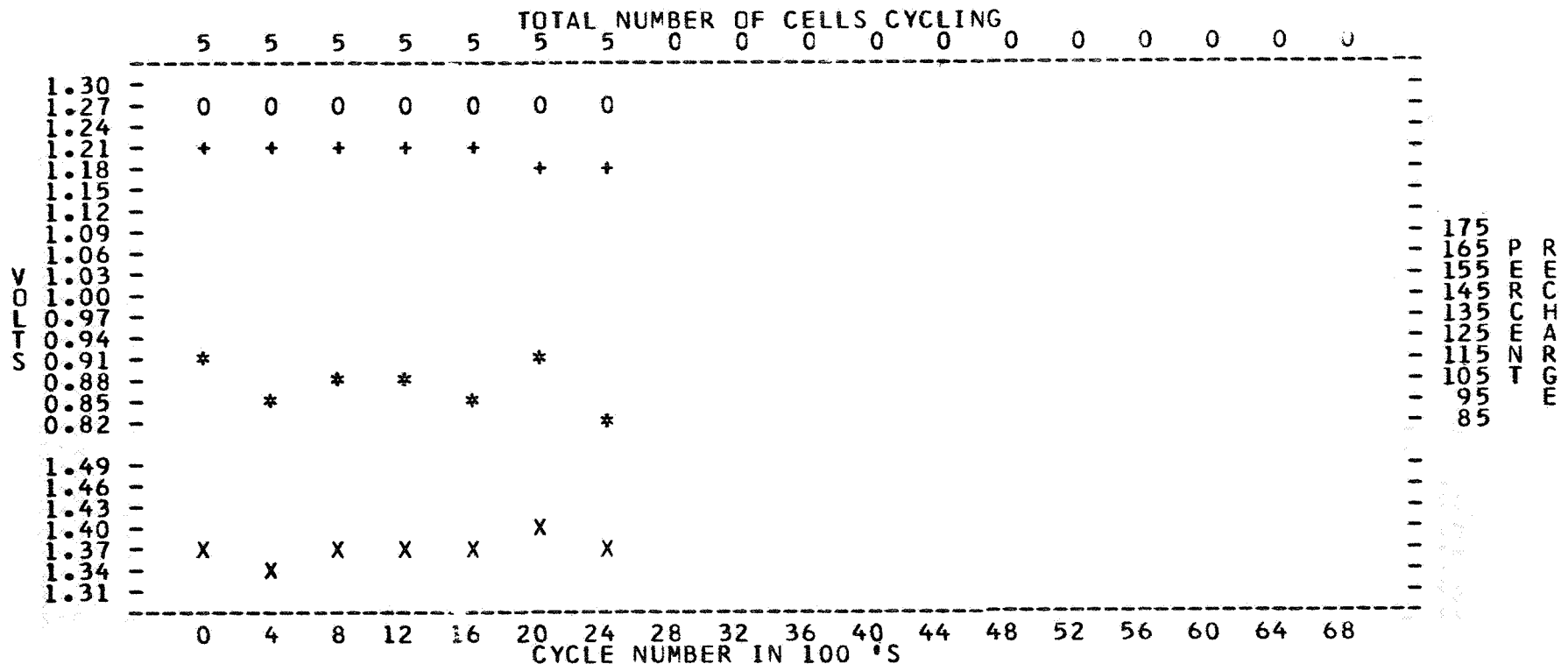
CAPACITY CHECK CYCLES
1415,

STATUS CELLS CYCLING 5
CYCLES COMPLETED 2423

RESISTOR VALUES: 82, 82, 82, 82, 82 OHMS. CYCLE 1713 TRIP VOLTAGE CHANGED TO 400 MV RESISTORS CHANGED TO 300 OHMS EACH CELL

FIGURE 38(G)

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 065B
TYPE OF CELLS GE 6.00 AH
TEST TEMPERATURE 0/40 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 3.00 AMP.

CAPACITY CHECK CYCLES
1386,

STATUS CELLS CYCLING 5
CYCLES COMPLETED 2529

RESISTOR VALUES 82, 82, 82, 82, 82 OHMS

FIGURE 38(H)

10. General Electric 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. One of the auxiliary electrodes is used for charge control. This electrode is welded to the inside of the container, and its terminal is a stainless steel tab welded to the outside. The other auxiliary electrode is used for gas recombination. It is welded to a wire that protrudes through a hole in the cell cover which is potted to seal the cell. Different values of resistance are used to connect the charge control and the gas recombination electrodes to the negative terminal. The cells were developed under contract NAS 5-10261.

b. Test Equipment: The charge current control circuit utilizes the auxiliary electrode voltage of each cell in the pack to reduce the charge rate after the cells have received the desired amount of recharge. The circuit is designed to monitor the auxiliary electrode voltage of each cell while the 5-cell pack is being charged. As the auxiliary electrode voltage of any cell of the pack approaches a preset value, the circuit begins to reduce the charge current. When the auxiliary electrode voltage of any cell reaches the predetermined voltage (trip voltage), the charge current is reduced to a preset trickle or to zero. The charge and discharge currents are supplied by a power supply.

c. Test Parameters:

Pack Number	Test Temperature	Percent Depth of Discharge	Trip Voltage Level (Millivolts)	Resistors on Cells (Ohms) Signal	Gas Recombination
53B	0° C	15	185	300	1
28C	25° C	15	70	10	1
47C	40° C	15	58	10	1

d. Test Results:

(1) Performance on cycling: (Figures 39(A) through 39(C).) Cycling was started in July 1968. These packs have completed from 2319 to 2399 cycles with no cell failures.

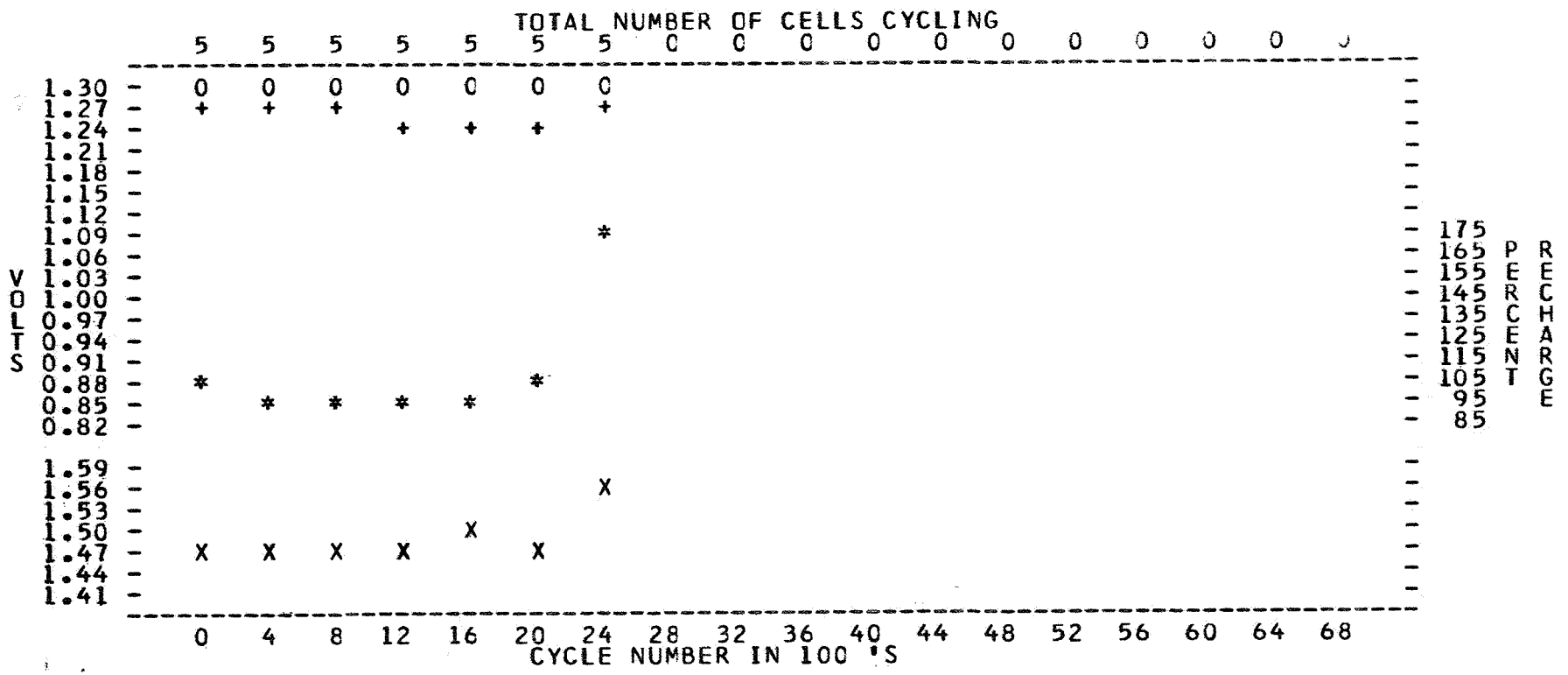
(2) Capacity checks: The ampere-hour capacities on the capacity check cycles are as follows:

CAPACITY CHECKS

Orbit Period	1.5-hour		
Temperature	0°	25°	40°
Depth of Discharge	15%	15%	15%
Pack Number	53B	28C	47C
88 Days	6.96	7.74	5.22

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 053B
TYPE OF CELLS GE 6.00 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 15 PERCENT
SPECIFIED CHARGE RATE 1.80 AMP.

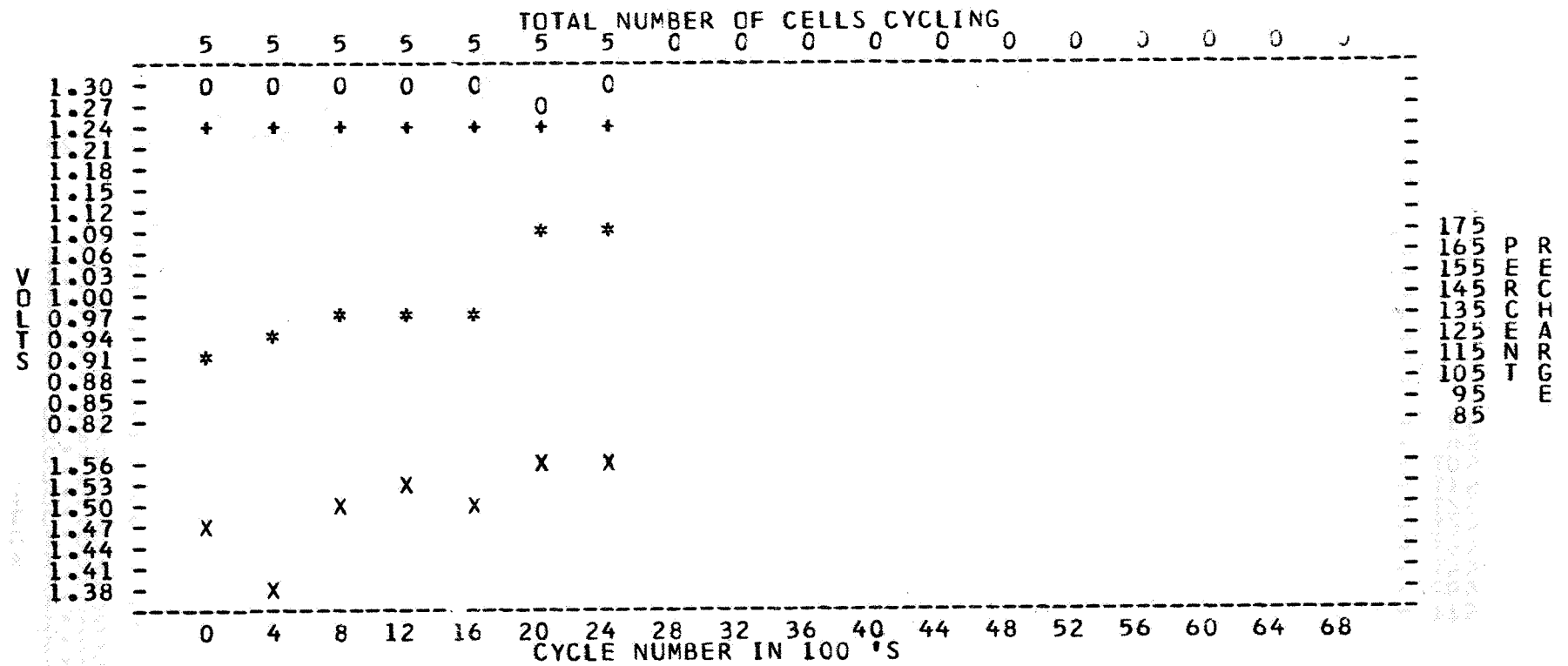
CAPACITY CHECK CYCLES
1370,

STATUS CELLS CYCLING 5
CYCLES COMPLETED 2319

RESISTOR VALUES: 300, 300, 300, OHMS. 3RD ELECTRODE RECOMBINATION
RESISTOR VALUES: 1, 1 OHM

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



POS. NO. CYCLE FAILED

PACK NUMBER 028C
TYPE OF CELLS GE 6.00 AH
TEST TEMPERATURE 25 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 15 PERCENT
SPECIFIED CHARGE RATE 1.80 AMP.

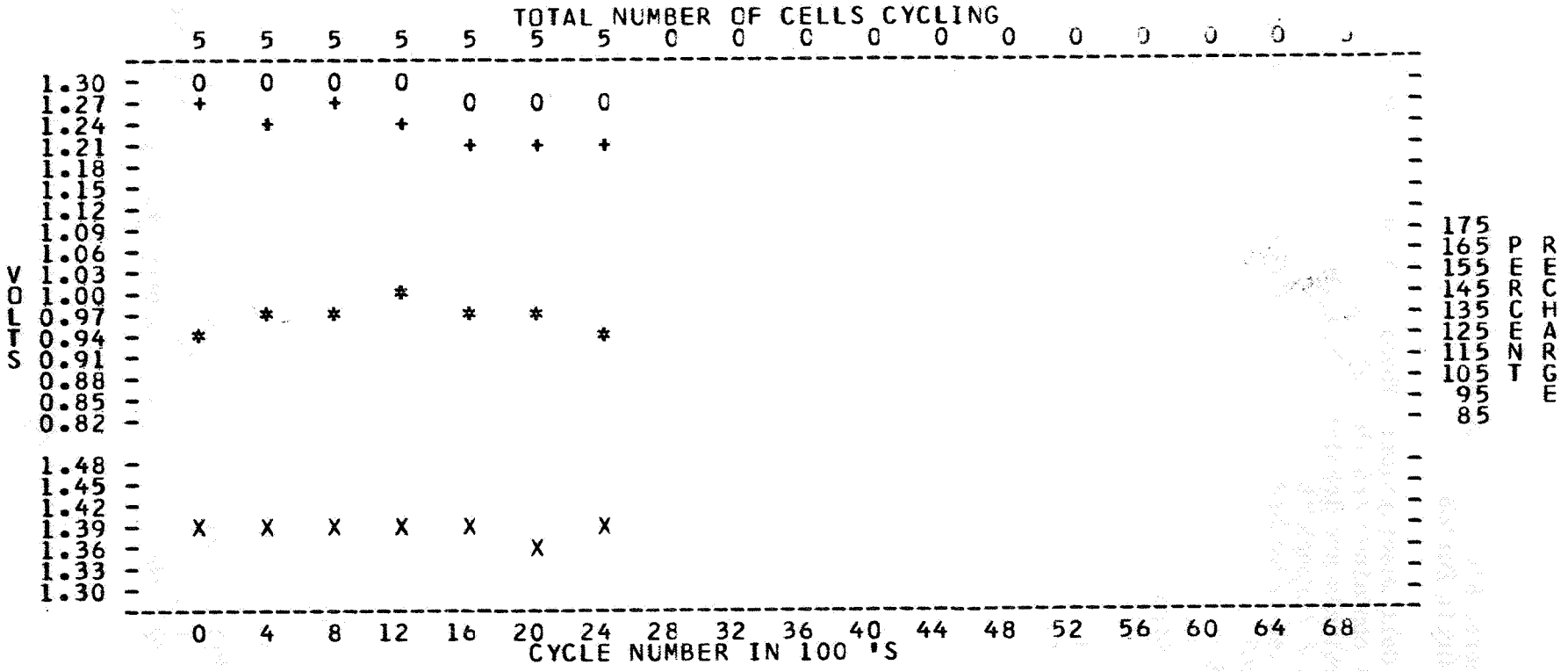
CAPACITY CHECK CYCLES
1450,

STATUS CELLS CYCLING 5
CYCLES COMPLETED 2399

RESISTOR VALUES: 10, 10, 10 OHMS THREE 3RD ELECTRODE CELL.RESISTOR VALUES 1, 1 OHM RECOMBINATION. DEPTH DISCHARGE CHANGED TO 25 & . CHARGE AND DISCHARGE CURRENT CHANGED TO 3.0 AMPS. CYCLE 1454. CYCLE 2448 50 MV TRIP VOLT

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



POS. NO. CYCLE FAILED

PACK NUMBER 047C
TYPE OF CELLS GE 6.00 AH
TEST TEMPERATURE 40 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 15 PERCENT
SPECIFIED CHARGE RATE 1.80 AMP.

CAPACITY CHECK CYCLES
1405,

STATUS CELLS CYCLING 5
CYCLES COMPLETED 2345

RESISTOR VALUES: 10, 10, 10, OHMS RECOMBINATION RESISTORS 1, 1 OHM
CYCLE 1856 DEPTH OF DISCHARGE CHANGED TO 25& CHARGE AND DISCHARGE CURRENT CHANGED TO 3.0 AMPS.

FIGURE 39(C)

11. 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.

b. Test Equipment: The charge current control circuit utilizes the auxiliary electrode voltage of each cell in the pack to reduce the charging rate after the cells have received the desired amount of recharge. The circuit is designed to monitor the auxiliary electrode voltage of each cell while the 5-cell pack is being charged. As the auxiliary electrode voltage of any cell of the pack approaches a preset value, the circuit begins to reduce the charge current. When the auxiliary electrode voltage of any cell reaches the predetermined voltage (trip voltage), the charge current is reduced to a preset trickle or to zero. The charge and discharge currents are supplied by a unit described in Section I, Paragraph IV.B.

c. Test Parameters:

Pack Number	Test Temperature	Percent Depth of Discharge	Trip 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. Cycling of Packs 60A, 12A, 24A and 48A was discontinued on cycles 5650, 1698, 665 and 5110 cycles respectively.

(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.

(e) Failure Analysis: Consultation with Goddard Space Flight Center and the manufacturer resulted in the decision to forego failure analyses of these cells since it was believed their poor performance was the result of questionable processing.

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

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	D	D
176 Days	Disch #1	13.40	7.60		
	Disch #2	14.60 D	15.10		
264 Days	Disch #1		7.90		
	Disch #2		11.50 D		

* 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.

D - Discontinued

12. 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 of each cell in the pack to reduce the charging rate after the cells have received the desired amount of recharge. The circuit is designed to monitor the auxiliary electrode voltage of each cell while the 5-cell pack is being charged. As the auxiliary electrode voltage of any 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 currents are supplied by a unit described in Section I, Paragraph IV.B.

c. Test Parameters:

Pack Number	Test Temperature	Percent Depth of Discharge	Trip 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. Packs 58A, 72A, 12B, 24B, 36A and 34A were discontinued on cycles 136, 304, 404, 38, 75 and 65 respectively. These packs showed excessive capacity losses in relatively few cycles as reflected in the capacity check data.

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

(a) Pack 58A, at 0° C: Precycling 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: Precycling 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: Precycling 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: Precycling 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: Precycling 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: Precycling 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.

(g) Failure Analyses: Consultation with Goddard Space Flight Center and the manufacturer resulted in the decision to forego failure analyses of these cells since it was believed their poor performance was the result of questionable processing.

13. 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 1 ohm.

(a) Following the low end-of-discharge voltage condition of one cell between cycles 1110 and 1136, the resistors on each of the five cells were changed to 50 ohms, at the request of Goddard Space Flight Center, to note any changes in the cell voltage characteristics.

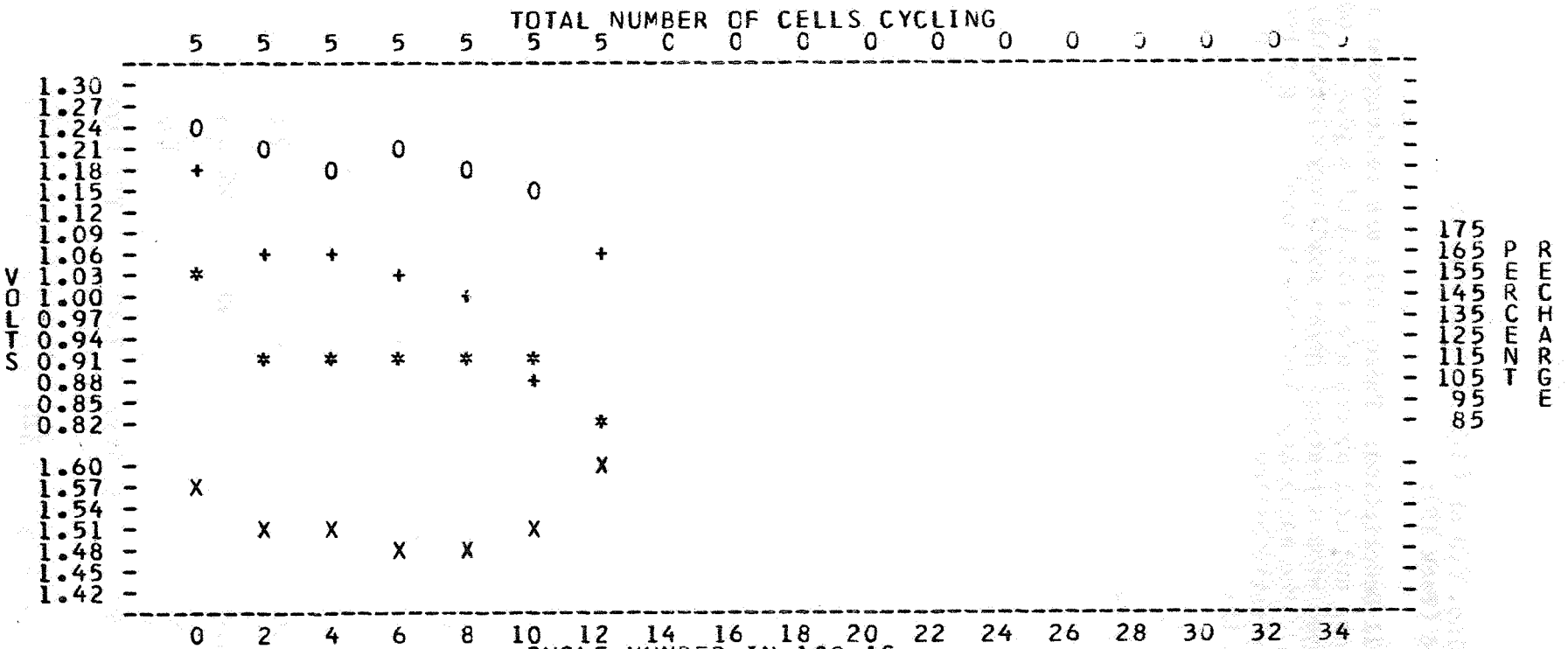
c. Test Results:

(1) Performance on cycling: (Figure 40.) Cycling was started in November 1967. This pack failed on cycle 1179 due to failure of three cells at that time as a result of severe migration of negative plate material. The positive plates of one cell were blistered; and imbedded in one was a piece of extraneous material which appeared to be plastic.

(2) Capacity checks: The ampere-hour capacity on precycling was 3.99 ampere-hours.

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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	1179
04	1179
05	1179

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 PACK FAILED
ON CYCLE NUMBER 1179

RESISTOR VALUES: 1, 1, 1, 1, 1 OHMS. CHANGED RESISTORS TO 51 OHMS
EACH CELL CYCLE 1138. TEST DISCONTINUED CYCLE 1179.

FIGURE 40

14. ESB, Inc. 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 gage, auxiliary electrode, and cellophane bellows. The auxiliary electrode is used for gas recombination only. The plastic bellows, located in the bottom of the cell, 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:

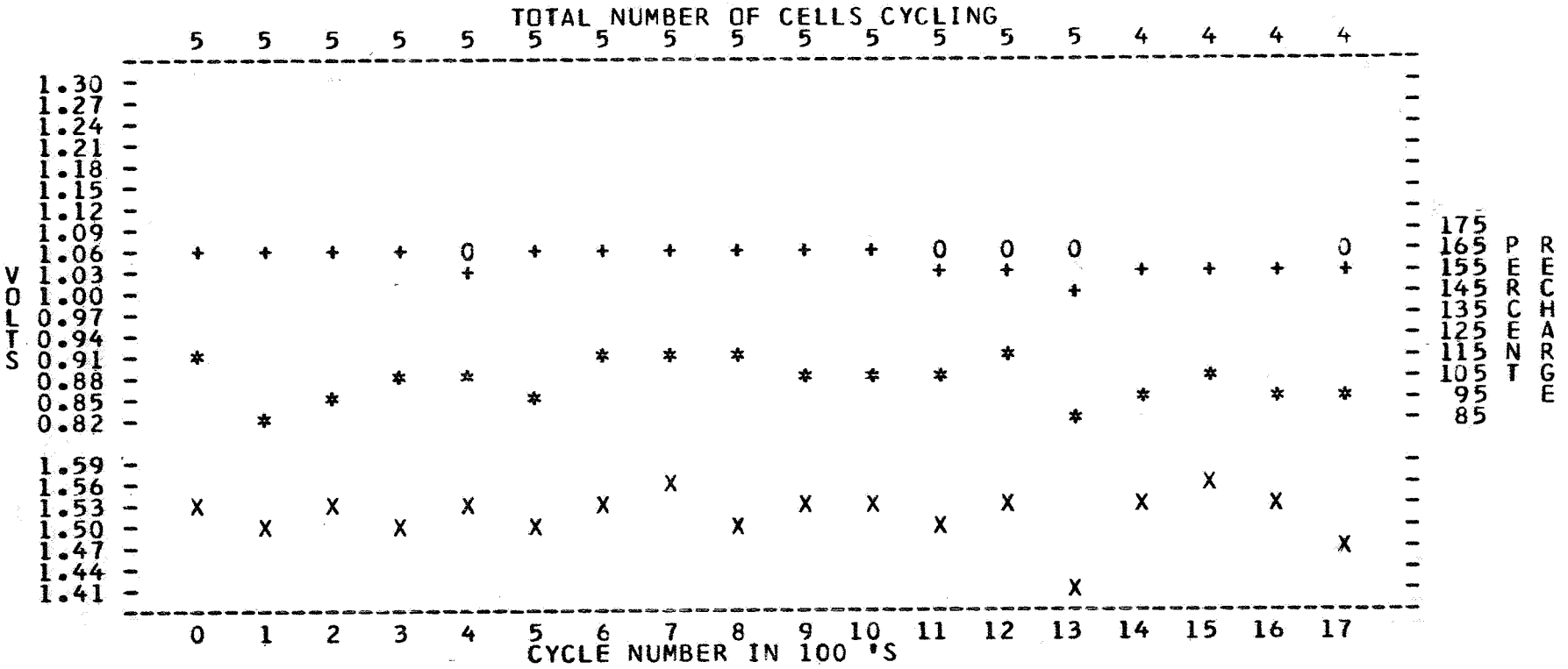
(1) Performance on cycling: (Figure 41.) Cycling was started in September 1966. This pack has completed 2371 cycles to date with one cell failure.

(a) One cell failed on cycle 1379 due to an internal short which caused the cell to develop high pressure resulting in the rupture of the plastic case.

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

Precycling	8.20	332 Days	9.07	568 Days	2.40
80 Days	12.67	365 Days	4.77	601 Days	6.73
106 Days	10.17	392 Days	3.73	629 Days	6.77
175 Days	12.27	425 Days	2.87	661 Days	6.40
211 Days	11.63	453 Days	4.83	694 Days	5.17
238 Days	12.43	475 Days	5.90	722 Days	4.80
290 Days	12.23	506 Days	7.53	754 Days	3.57
304 Days	11.50	533 Days	7.77	787 Days	3.40

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



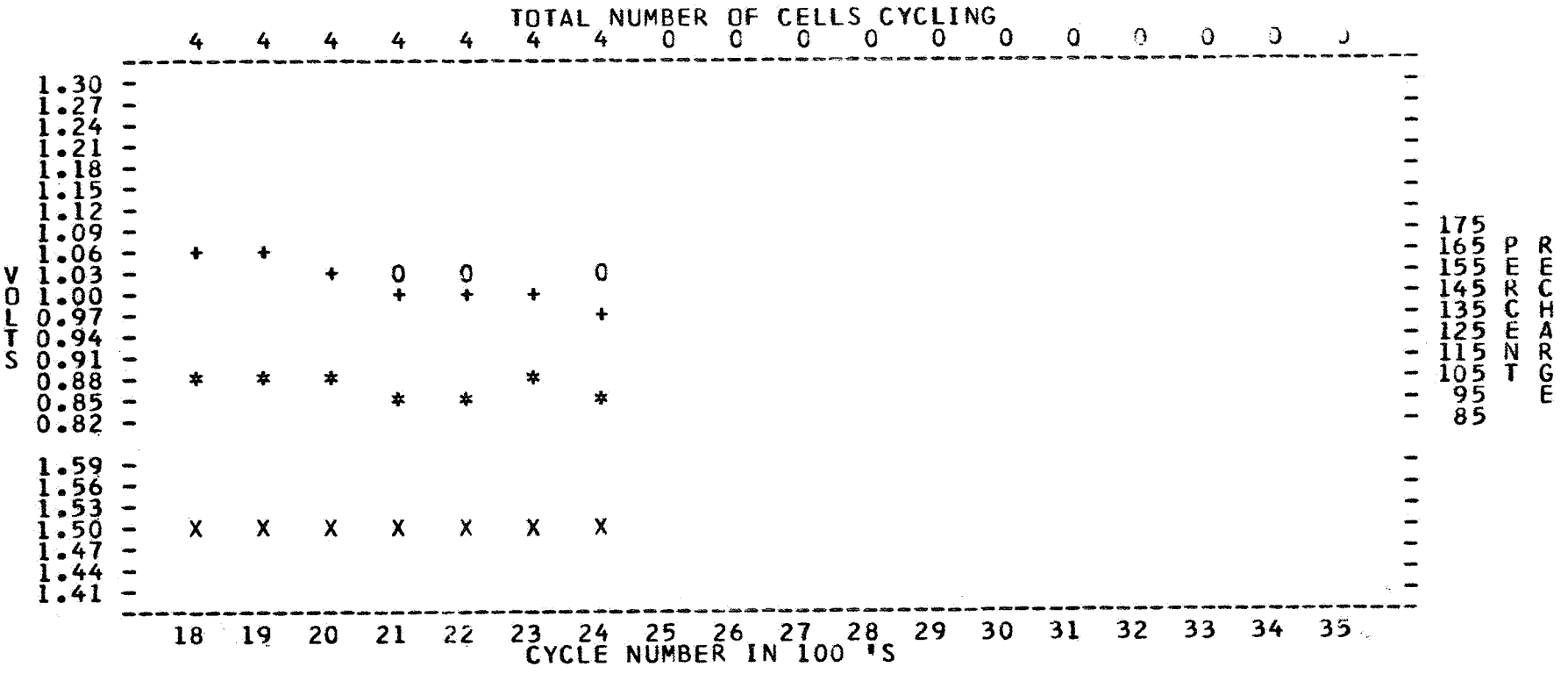
POS. NO.	CYCLE FAILED	PACK NUMBER	001B	CAPACITY CHECK CYCLES
04	1379	TYPE OF CELLS	ESB 8.00 AH	240, 319, 524, 630, 711
		TEST TEMPERATURE	25 DEGREES C.	807, 909, 995, 1094, 1175
		ORBIT PERIOD	08.0 HOURS	1274, 1356, 1423, 1517, 1596
		DEPTH OF DISCHARGE	25 PERCENT	1701, 1801, 1886, 1980, 2080
		SPECIFIED CHARGE RATE	0.50 AMP.	2165, 2259, 2359, 0, 0

STATUS CELLS CYCLING 4
CYCLES COMPLETED 2371

RESISTOR VALUES: 2.2, 2.2, 2.2, 2.2, 2.2 OHMS
CYCLE 742: ALL RESISTORS REMOVED.

FIGURE 41

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. 04 — CYCLE FAILED 1379

PACK NUMBER	001B
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,	1356,	1423,	1517,	1596
1701,	1801,	1886,	1980,	2080
2165,	2259,	2359,	0,	0

STATUS CELLS CYCLING 4
CYCLES COMPLETED 2371

RESISTOR VALUES: 2.2, 2.2, 2.2, 2.2, 2.2 OHMS
CYCLE 742: ALL RESISTORS REMOVED.

FIGURE 41 (CONTD)

15. Yardney 11.0 ah (Silver-Cadmium), Three 5-cell Packs, 24-hour Orbit Period:

a. Cell Description: These cells are rectangular in shape. The cell jars and covers are made of a plastic material. An auxiliary electrode (adhydrode type) was installed in each cell by Goddard Space Flight Center before being individually epoxy potted with a wrap of fiber glass material to hermetically seal and strengthen them. The auxiliary electrode is used for gas recombination only.

b. Test Parameters:

Pack Number	Test Temperature	Percent Depth of Discharge	Charge Voltage Limit, Per Cell	Resistors On Cells (Ohms)
57D	0° C	18	1.51	1
69B	25° C	18	1.51	1
33C	40° C	18	1.51	1

c. Test Results:

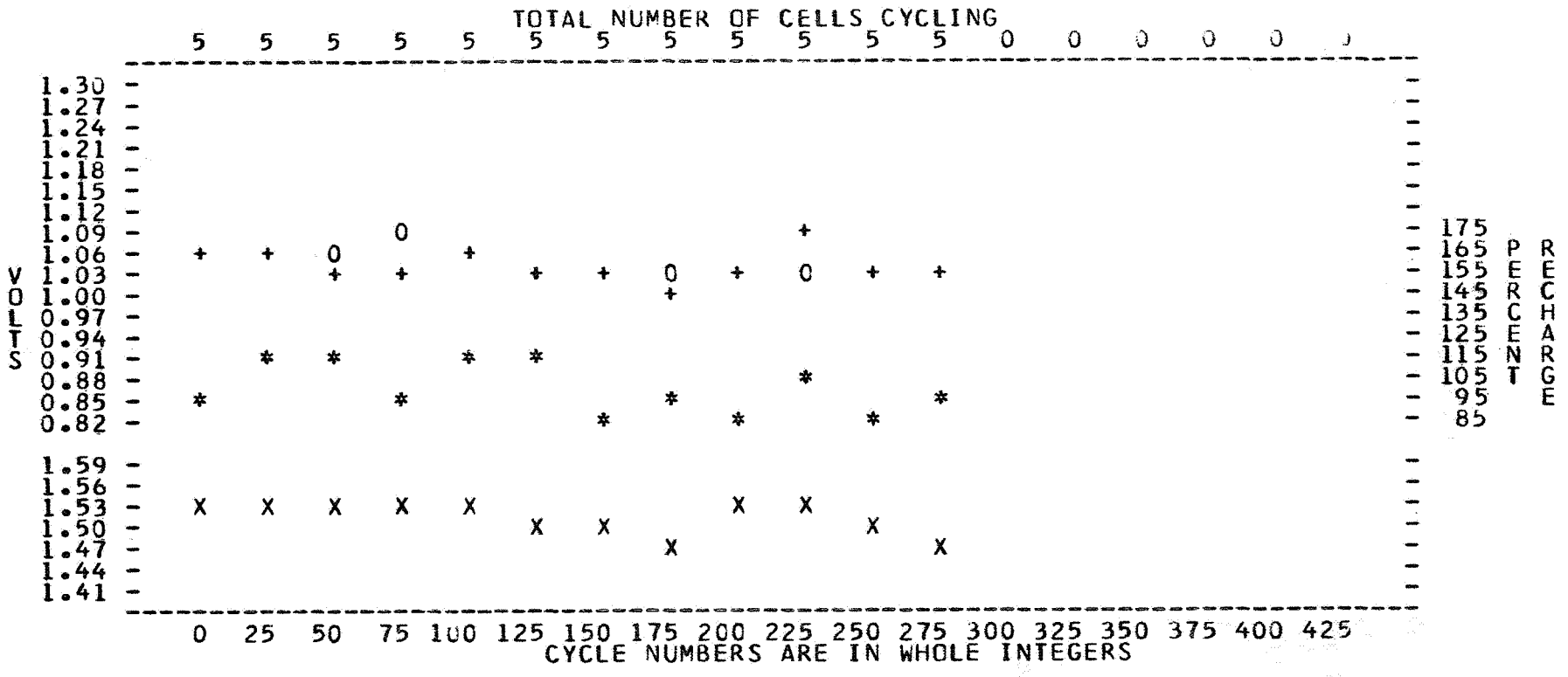
(1) Performance on cycling: (Figures 42(A) through 42(C).) Cycling was started in February 1968. Packs 57D, 69B and 33C have completed 295, 304 and 303 cycles, respectively, with no cell failures.

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

Pack Number	57D	69B	33C
100 Days	4.10	7.55	8.70
200 Days	7.20	7.00	6.85
300 Days	4.10	3.50	5.15

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 057D
TYPE OF CELLS YARDNEY 11.00 AH
TEST TEMPERATURE 00 DEGREES C.
ORBIT PERIOD 24.0 HOURS
DEPTH OF DISCHARGE 18 PERCENT
SPECIFIED CHARGE RATE 0.25 AMP.

CAPACITY CHECK CYCLES
99, 188, 271,

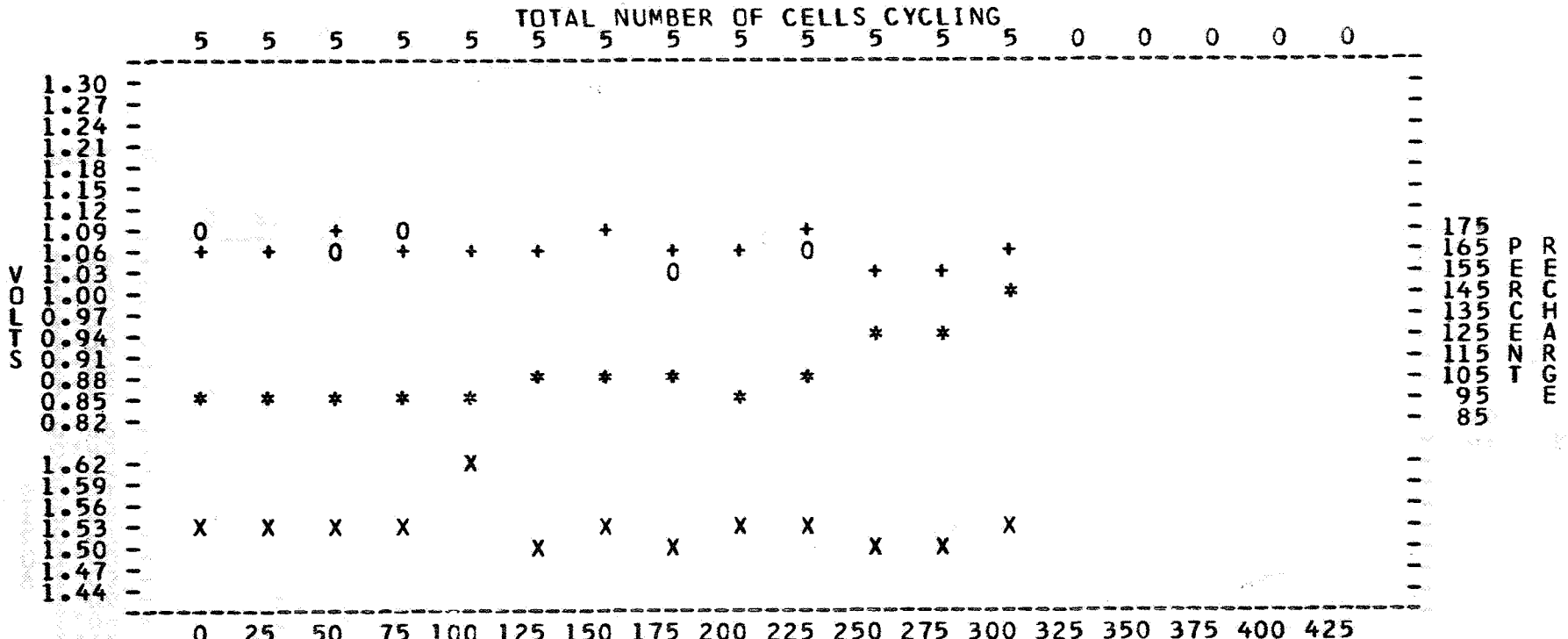
STATUS CELLS CYCLING 5
CYCLES COMPLETED 295

RESISTOR VALUES: 1, 1, 1, 1, 1 OHM

FIGURE 42(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 0698
TYPE OF CELLS YARDNEY 11.00 AH
TEST TEMPERATURE 25 DEGREES C.
ORBIT PERIOD 24.0 HOURS
DEPTH OF DISCHARGE 18 PERCENT
SPECIFIED CHARGE RATE 0.25 AMP.

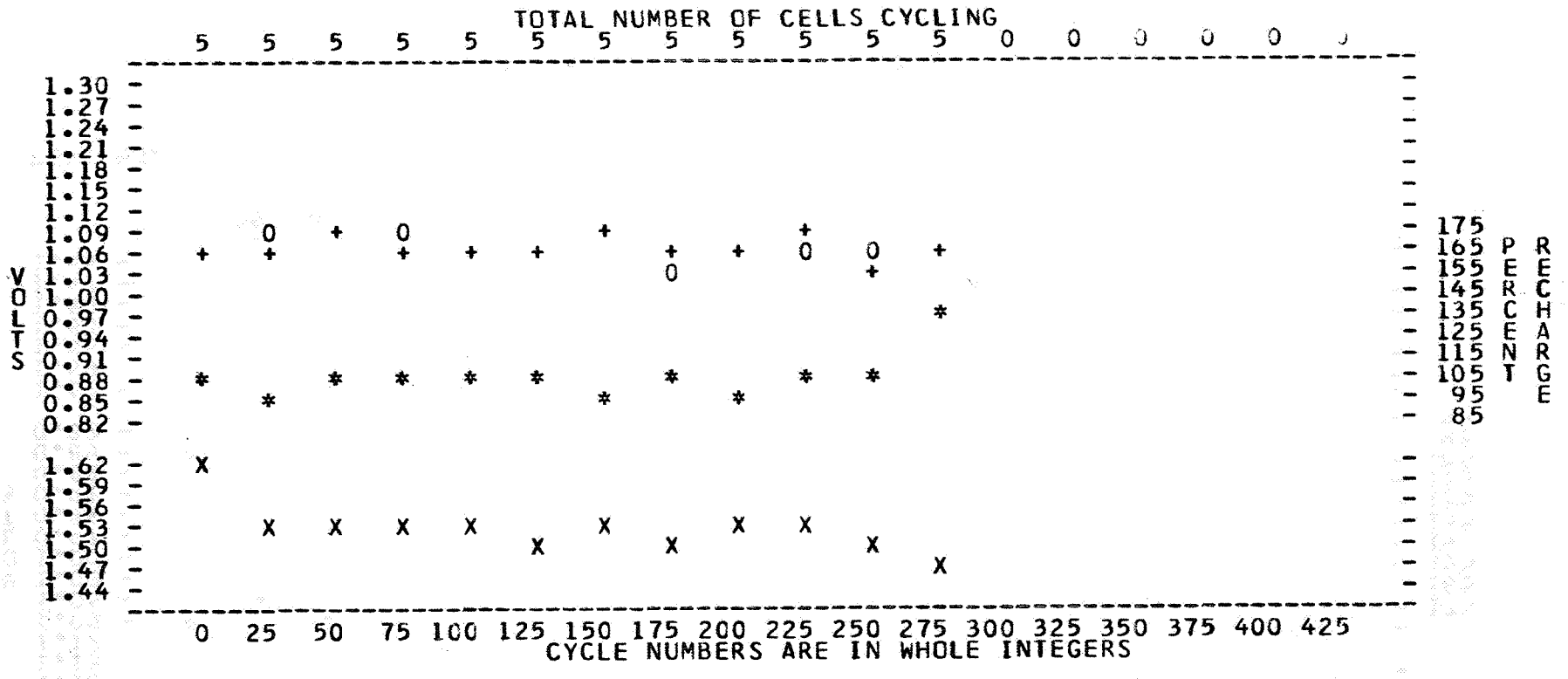
CAPACITY CHECK CYCLES
99, 189, 279,

STATUS CELLS CYCLING 5
CYCLES COMPLETED 304

RESISTOR VALUES 1, 1, 1, 1, 1 OHMS

FIGURE 42(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. CYCLE FAILED

PACK NUMBER 033C
TYPE OF CELLS YARDNEY 11.00 AH
TEST TEMPERATURE 40 DEGREES C.
ORBIT PERIOD 24.0 HOURS
DEPTH OF DISCHARGE 18 PERCENT
SPECIFIED CHARGE RATE 0.25 AMP.

CAPACITY CHECK CYCLES
99, 189, 279,

STATUS CELLS CYCLING 5
CYCLES COMPLETED 303

CYCLE 30: ELECTROLYTE LEAKING.
RESISTOR VALUES: 1, 1, 1, 1, 1 OHMS.

FIGURE 42(C)

16. 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. A fuel cell type auxiliary electrode for gas recombination was installed in each cell by Goddard Space Flight Center before being individually epoxy potted with a wrap of fiber glass material 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.

(a) Pack 21D: This pack failed on cycle 60 due to low capacity of several cells.

(b) Pack 9F: The first of four cell failures occurred on cycle 258, the second on cycle 288, and the remaining two on cycle 310.

(c) The two packs were returned to Goddard Space Flight Center for failure analysis.

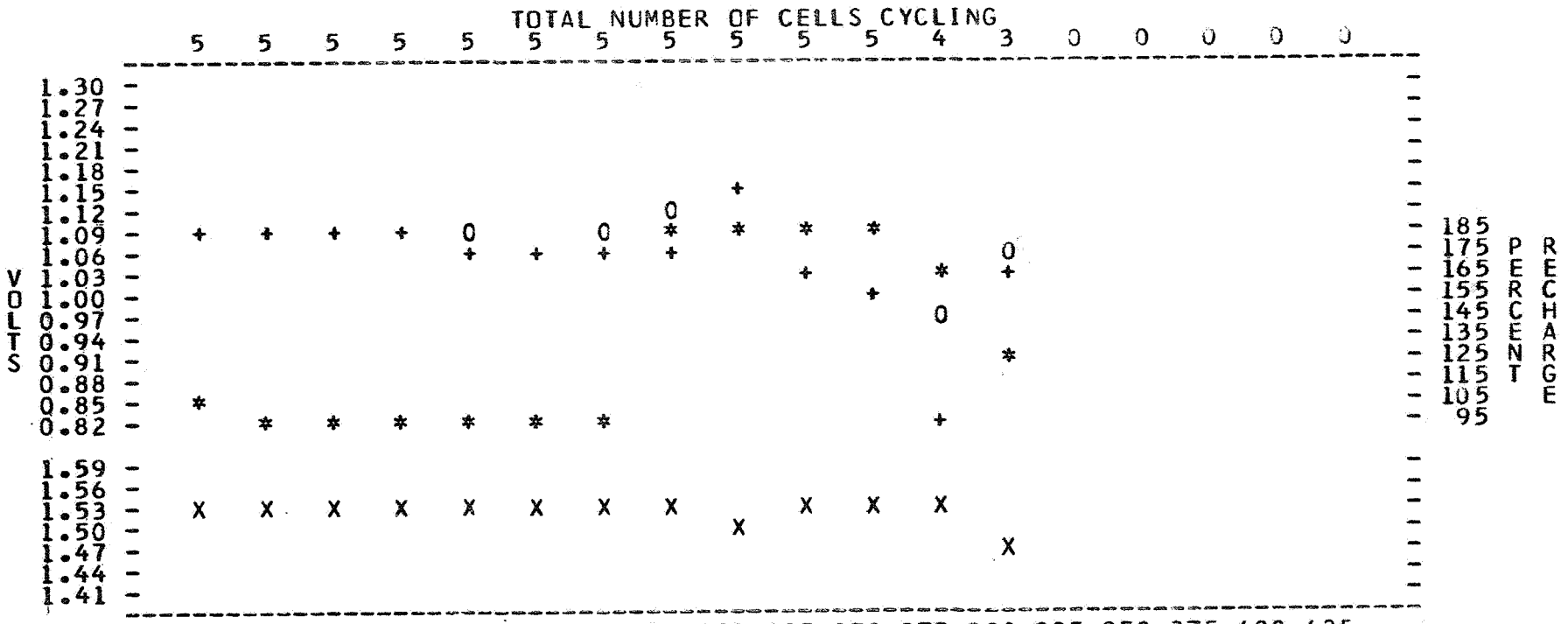
(2) Capacity checks: The ampere-hour capacities on the precycling and capacity check cycles are as follows:

Pack Number	21D	9F
Precycling Capacity	4.33	5.53
100 Days	F	8.33
200 Days		7.60
273 Days		5.33 F

F - Failed

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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	258
05	288
03	310
04	310

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, 206, 271,

STATUS PACK FAILED
ON CYCLE NUMBER 310

CYCLE 26: ELECTROLYTE LEAK. CYCLE 258 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 reaced 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 currents are supplied by equipment described in Section I, Paragraph IV.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 type cell was used 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 at cycle 48 the depth of discharge was reduced to 15 percent, with all other parameters unchanged.

(2) It was necessary to recharge all packs at the c/1 rate (5 amperes) since the 5-ampere stabistor (with heat sink) in parallel with each cell was designed to maintain the proper stabistor temperature for the correct breakdown voltage when shunting the 5 amperes.

c. Test Results:

(1) Performance on cycling: Cycling was started in August 1965. The break-down voltage of the stabistors was too high for proper voltage limiting, thereby resulting in excessive gassing and high internal pressure. This in turn caused leakage as evidenced by carbonate deposits around the ceramic seal of the terminal of 26 of the 29 failed cells, of which the containers of 23 cells were bulged. The remaining contributory causes of pack failures and cycle at which the respective packs failed are as follows:

(a) Pack 75C failed on cycle 2145. On cycle 353, a new cell replaced the first cell failure at that cycle, which itself failed on cycle 2145. The other two cell failures occurred on cycles 1448 and 1601. These four failed cells showed the effects of excessive scoring with migration of negative plate material greater in the scored areas, and weak welds between the tabs and the positive plates.

(b) Pack 89B failed on cycle 1530. On cycle 111, two new cells replaced the first two cell failures at that cycle, one of which failed on cycle 1337. The other two cell failures occurred at cycles 495 and 1530. Failure analysis was performed on only the first three of the five failed cells. The three cells showed weak welds between the tabs and positive plates. The plates of two cells showed the effects of excessive scoring with migration of negative material greatest in the scored areas.

(c) Pack 92A failed on cycle 8774 when two of the three cell failures occurred. The first cell failure occurred on cycle 5788. The three failed cells had ceramic shorts, weak welds between the tabs and positive plates and migration of negative plate material. The plates of two cells showed the effects of excessive scoring, and one cell showed separator deterioration.

(d) Pack 122B failed on cycle 5190 when the third of three cell failures occurred. The first two cell failures occurred on cycles 1908 and 4181. The three cells showed migration of negative

plate material and had weak welds between the tabs and positive plates. The plates of one cell showed the effects of excessive scoring and the positives were blistered. The positive plates of one cell had some loosened active material.

(e) Pack 73B failed on cycle 3742 when the third of three cell failures occurred. The first two cell failures occurred on cycles 2342 and 2774. In the three cells, the plates showed the effects of excessive scoring and migration of negative plate material, two cells showed separator deterioration. In the three cells, the welds between the tabs and positive plates were weak, and one of the cells had a ceramic short.

(f) Pack 87B failed on cycle 2392 when two of the four cell failures occurred. The first two cell failures occurred on cycles 948 and 1513. In the four cells, the plates showed the effects of excessive scoring and migration of negative plate material, one cell showed separator deterioration. In the four cells, the welds between the tabs and positive plates were weak; and two cells had ceramic shorts, one of which had some extraneous active material.

(g) Pack 99B failed on cycle 4388 when two of the three cell failures occurred. The first cell failure occurred on cycle 3216. The three failed cells showed migration of negative plate material, separator deterioration and weak welds between the tabs and positive plates. The plates of two cells showed the effects of excessive scoring and the positives of one cell were blistered.

(h) Pack 112B failed on cycle 3294 when three of the four cell failures occurred. The first cell failure occurred on cycle 1613. The four failed cells had ceramic shorts, and weak welds between the tabs and positive plates. The plates showed the effects of excessive scoring with migration of negative plate material greatest in the scored areas.

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

PRECYCLING 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
Precycling 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 F	2.58 F	2.75	2.33	2.33	3.66 F	1.88	1.04 F
176 Days	Disch #1			1.75	2.63	1.17		1.17	
	Disch #2			1.71	1.50	1.29 F		1.50	
264 Days	Disch #1			1.25	1.63			1.13	
	Disch #2			0.75	0.79			1.17 F	
352 Days	Disch #1			1.17	1.75				
	Disch #2			*	* F				
440 Days	Disch #1			1.46					
	Disch #2			1.38 F					

* Cell failure occurred during capacity check.

F - Failed

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 reduced to cadmium by the passage of charge, the other set is oxidized 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 (Nickel-Cadmium with Neoprene Seal), One 10-cell Pack, 1.5-hour Orbit Period (Pack 39B):

a. Cell Description: These are cyclindrical cells with a folded neoprene seal as described in Section II, Paragraph I.A.4.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 currents for the pack are supplied by a unit which is described in Section I, Paragraph IV.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 failure by self destruction. During recharge following the first capacity check after cycle 5399, one or more cells of the seven cells cycling shorted and caught fire. All seven cells were completely destroyed thereby

preventing failure analysis. The coulometer failed after 1868 cycles due to loss of capacity. The end-of-discharge voltage improved after a new coulometer was placed in the pack.

(a) The first three cell failures occurred at cycles 2182, 4949 and 4976. The three cells showed migration of negative plate material and separator deterioration. The positive plates of the three cells had loosened active material and were blistered. The welded seam of each of the three cells showed leakage as evidenced by deposits.

(b) The single nonwoven nylon separator used in this coulometer was not adequate to prevent early shorting due to cadmium migration. Cadmium-cadmium coulometers must have at least twice the amount of plate separation as regular nickel-cadmium cells and are operated in the flooded state. At least two layers of nonwoven nylon are recommended to retard migration to a point less than that in the nickel-cadmium cell.

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

Precycling	3.06
88 Days	2.07
176 Days	2.01
264 Days	2.55
352 Days	1.71 F

F - 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. The containers and covers are of a plastic material. 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 44(A) and 44(B).) Pack 40C failed during precycling at -20° C due to high internal pressure which cracked several cells and the molded epoxy covering. Cycling of the remaining six packs was started in March 1967.

(a) At the request of Goddard Space Flight Center, cycling of any pack was stopped upon failure of any cell within the pack since there was no way of removing individual failed cells electrically from the pack. No failure analyses were performed because failure of these commercial cells was due to high pressure resulting from too much electrolyte which caused the cells to rupture.

(b) Pack 26C completed 10,317 cycles to date with no cell failures.

(c) One cell in each of Packs 52B, 14C, 38D and 39C failed on cycles 5685, 2428, 1927 and 1508 respectively, thereby terminating the test on these packs.

(d) Pack 37 C failed on cycle 790 due to high internal cell pressure which caused the molded epoxy covering to crack open between cells 2 and 3. Although none of the individual cells were ruptured, cells 2 and 3 particularly were bulged excessively. The entire pack was very hot at time of failure.

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

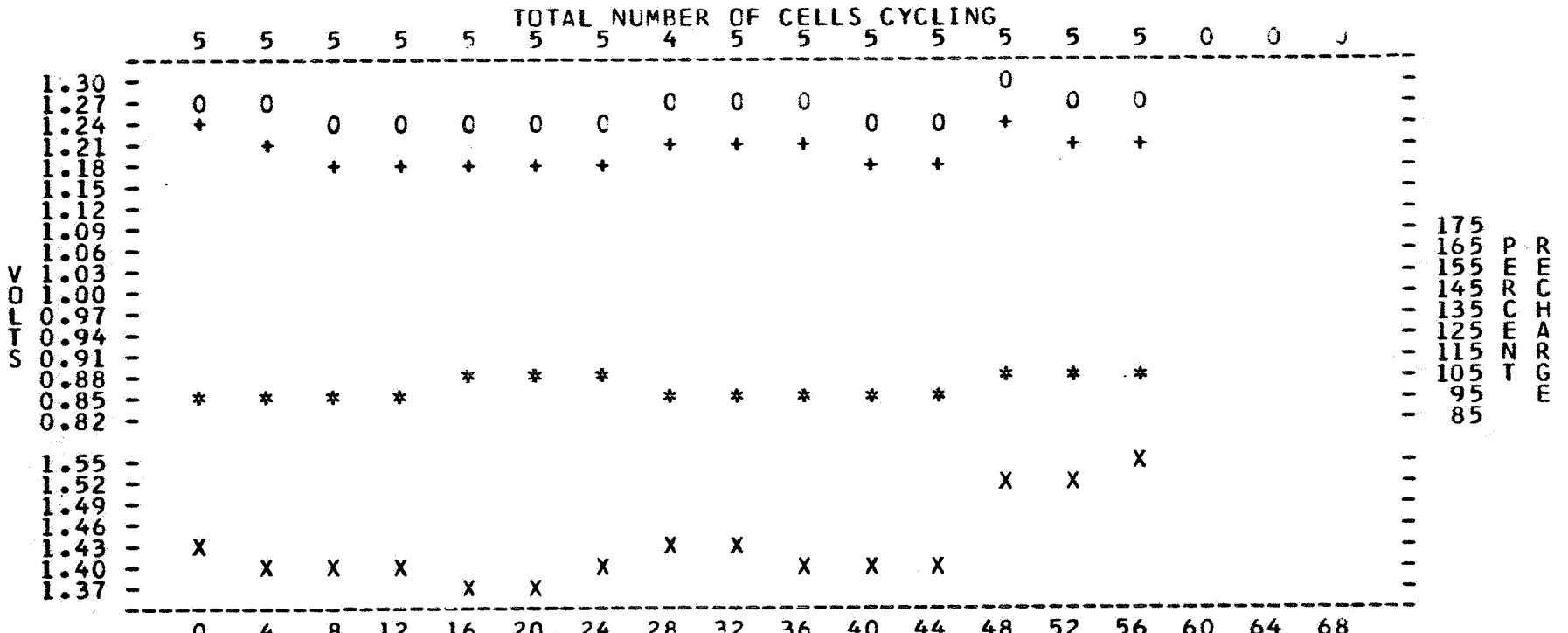
Orbit Period		1.5-hour						
Temperature		-20°	0°	25°	25°	25°	25°	40°
Depth of Discharge		25%	25%	15%	25%	40%	60%	25%
Pack Number		40C	52B	26C	14C	37C	38D	39C
Precycling Capacity		*	4.43	4.67	4.23	5.03 F	4.57	3.30
88 Days	Disch #1		3.43	3.50	3.00		2.00	0.97
	Disch #2		4.10	3.10	3.50 F		1.87 F	1.13 F
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				
352 Days	Disch #1		3.67	3.67				
	Disch #2		3.80 F	3.37				
440 Days	Disch #1			3.13				
	Disch #2			3.40				
528 Days	Disch #1			2.17				
	Disch #2			2.33				
616 Days	Disch #1			1.20				
	Disch #2			1.33				
704 Days	Disch #1			0.67				
	Disch #2			0.93				

* Pack failure occurred during precycling capacity check.

F - Failed

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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. 05 CYCLE FAILED 5685

PACK NUMBER 052B
TYPE OF CELLS GULTON 4.00 AH
TEST TEMPERATURE 25 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 00 PERCENT
SPECIFIED CHARGE RATE 2.00 AMP.

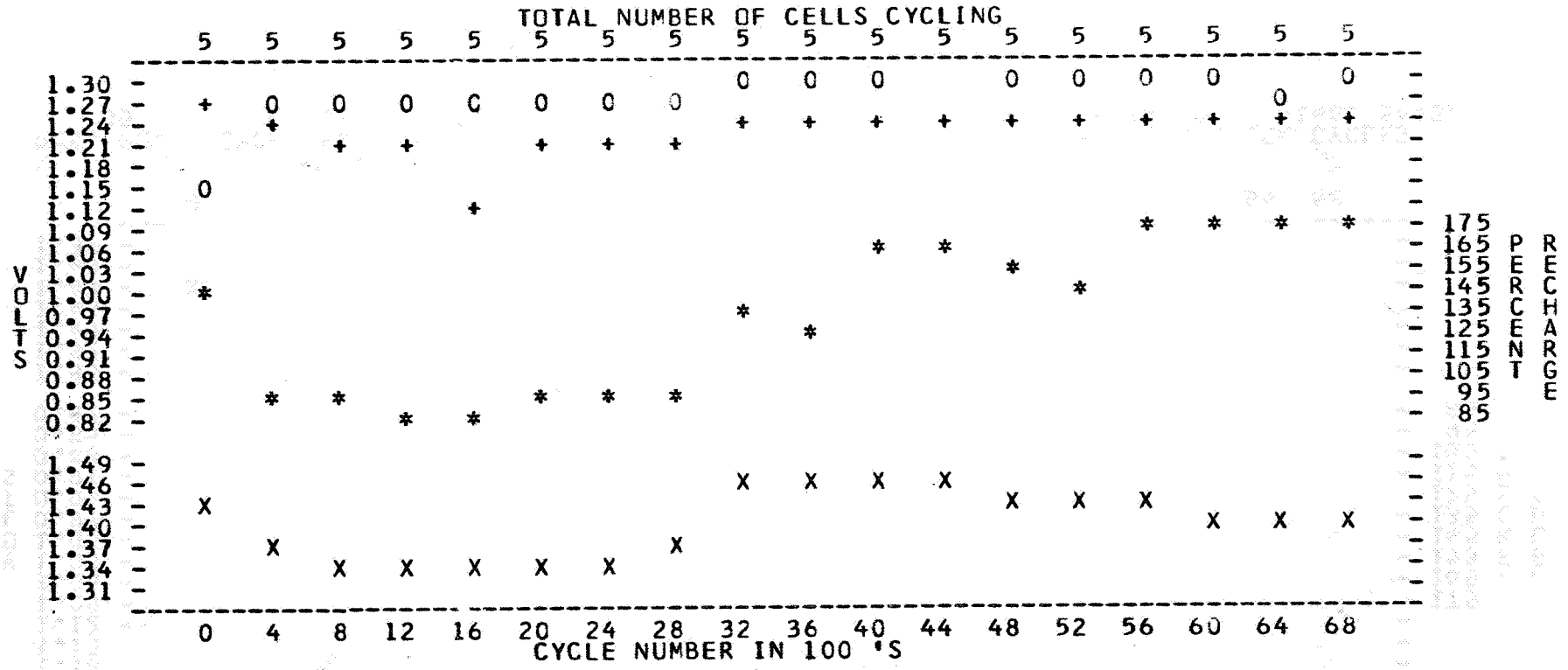
CAPACITY CHECK CYCLES
1441, 2704, 4146, 5645,

STATUS PACK FAILED
ON CYCLE NUMBER 5685

FIGURE 44(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 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.

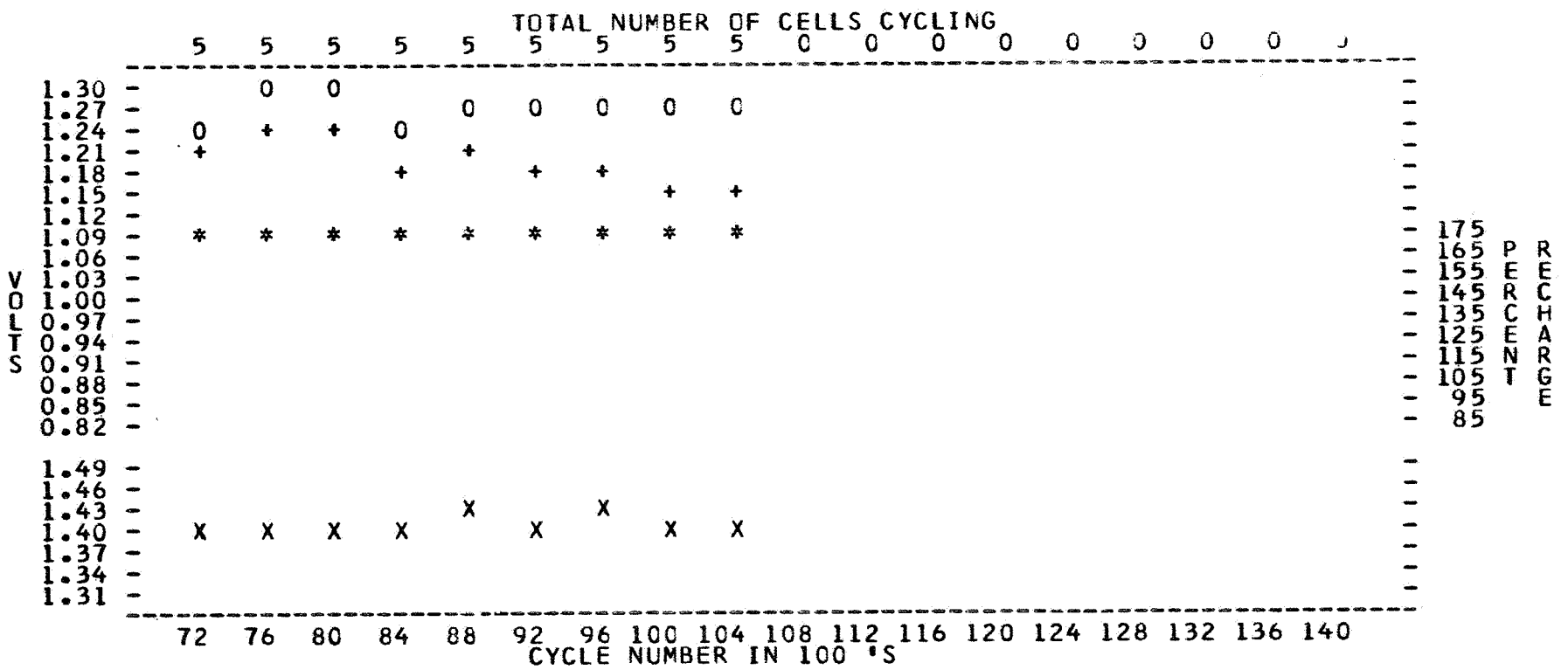
STATUS CELLS CYCLING 5
CYCLES COMPLETED 10317

CAPACITY CHECK CYCLES
1386, 2711, 4089, 5383, 6791
7972, 9379,

VOLTAGE LIMIT SET TOO HIGH 7.90 VOLTS. CYCLE 92 CHANGED VOLTAGE LIMIT TOO 7.30 VOLTS. CYCLE 185 CHANGED VOLTAGE LIMIT TO 7.40 VOLTS.

FIGURE 44(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. 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, 5383, 6791
7972, 9379,

STATUS CELLS CYCLING 5
CYCLES COMPLETED 10317

VOLTAGE LIMIT SET TOO HIGH 7.90 VOLTS. CYCLE 92 CHANGED VOLTAGE LIMIT TOO 7.30 VOLTS. CYCLE 185 CHANGED VOLTAGE LIMIT TO 7.40 VOLTS.

FIGURE 44(B) (CONTD)

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 45(A) through 45(D).) Cycling was started in November 1966. Packs 41B, 66B, 18C and 29B have completed 5695, 5898, 5465 and 5833 cycles respectively to date with one cell failure on Pack 18C at cycle 2345. Failure analysis of the one cell showed high internal pressure in the form of residual gas, and severe localized migration of negative material which permitted low resistance shorting paths between the negative and positive plates.

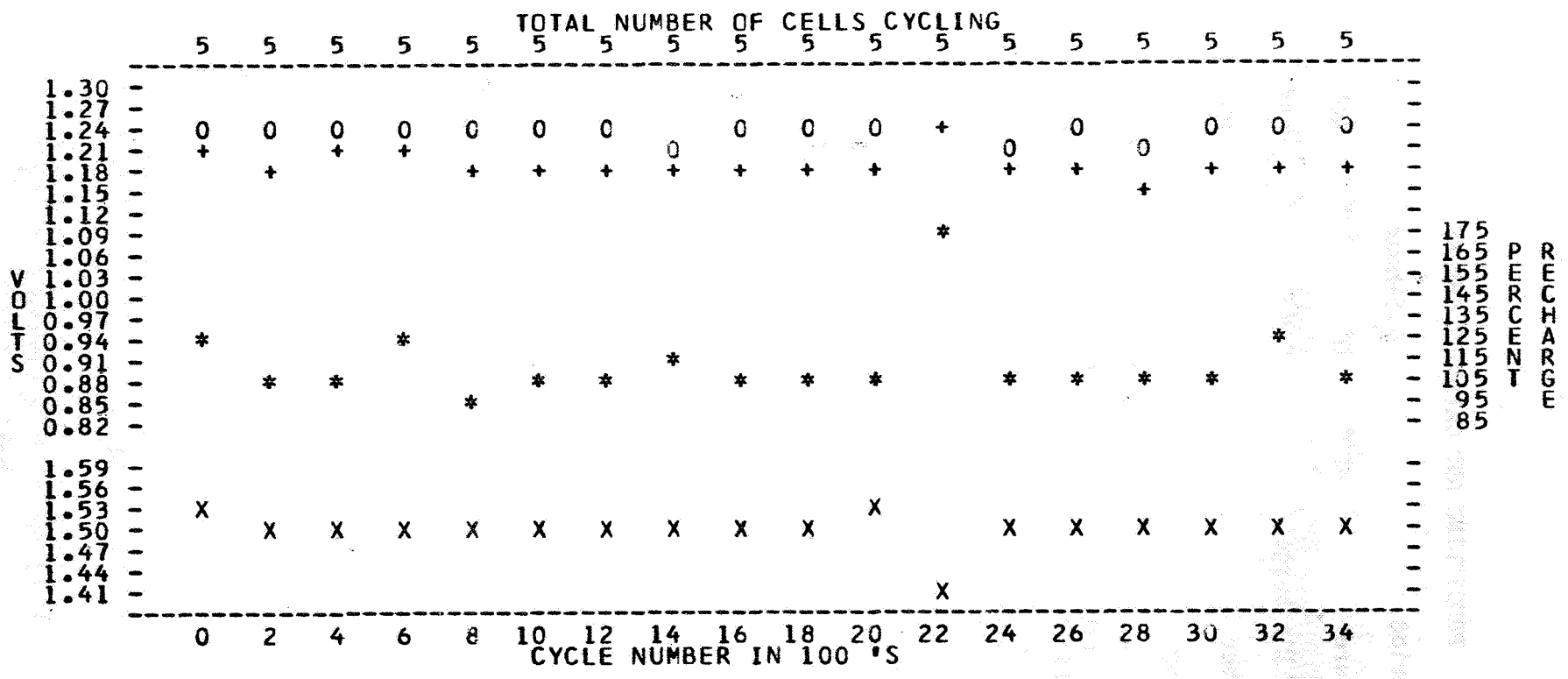
(a) Coulometers: It was necessary to replace the coulometer in Pack 41B, operating at -20° C, on six occasions; and on one occasion in Pack 66B operating at 0° C. These failures were due to inadequate plate separation having one layer of nonwoven nylon. Coulometers require twice the effectiveness of plate separation as that found in its nickel-cadmium counterpart. The failure mode being combated is cadmium migration. At least two nonwoven nylon layers are used in RAE coulometers. The cells have operated satisfactorily with coulometer control at all test temperatures.

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

PRECYCLING 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
Precycling 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
352 Days	Disch #1	3.05	5.35	1.45	1.50
	Disch #2	3.25	5.25	1.50	1.60
440 Days	Disch #1	3.00	4.75	1.20	1.55
	Disch #2	3.05	4.75	1.35	1.55
528 Days	Disch #1	1.05	4.55	1.50	1.55
	Disch #2	0.90	4.55	1.50	1.60
616 Days	Disch #1	2.25	3.75	1.40	1.45
	Disch #2	2.40	4.00	1.50	1.50

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 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.

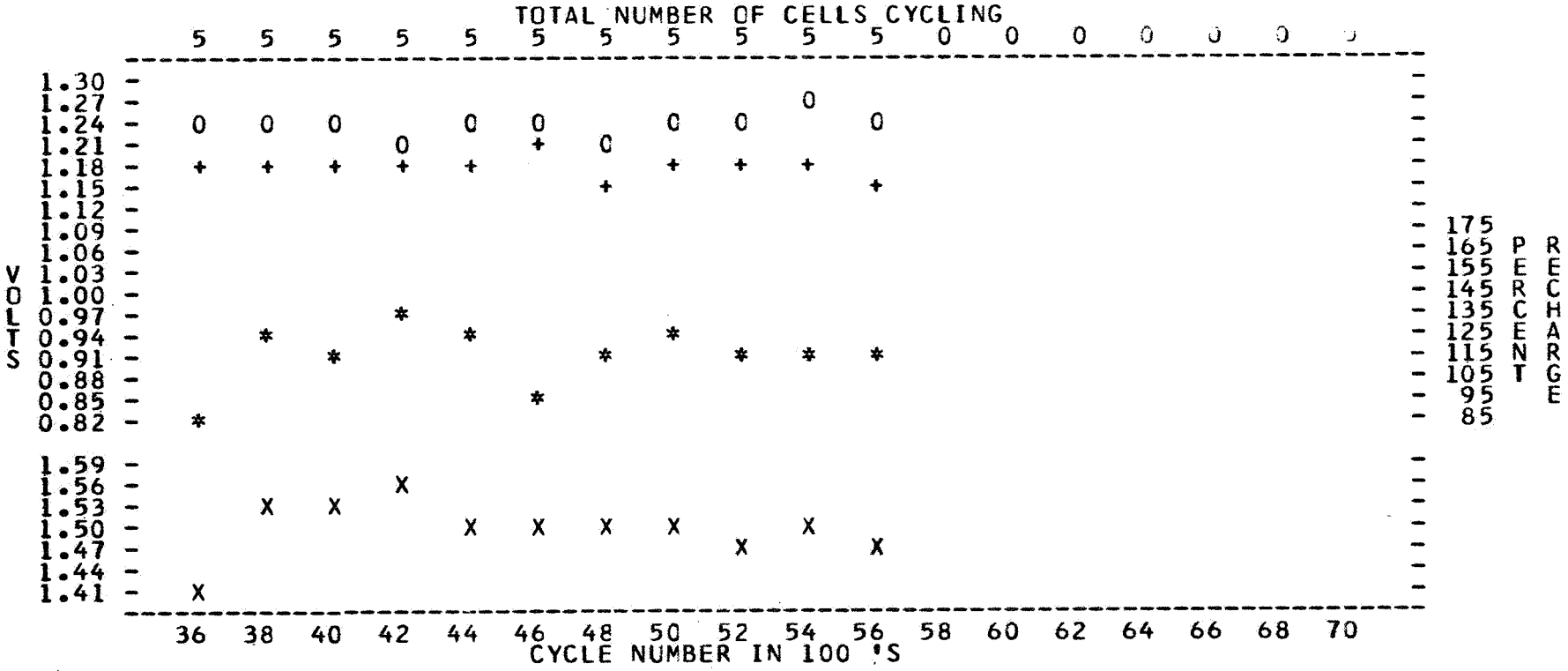
STATUS CELLS CYCLING 5
CYCLES COMPLETED 5695

CAPACITY CHECK CYCLES
889, 1706, 2244, 2893, 3598
4303, 5008,

CYCLE 3513 COULOMETER CHANGED. CYCLE 4306 COULOMETER CHANGED.

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



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, 2893, 3598
4303, 5008,

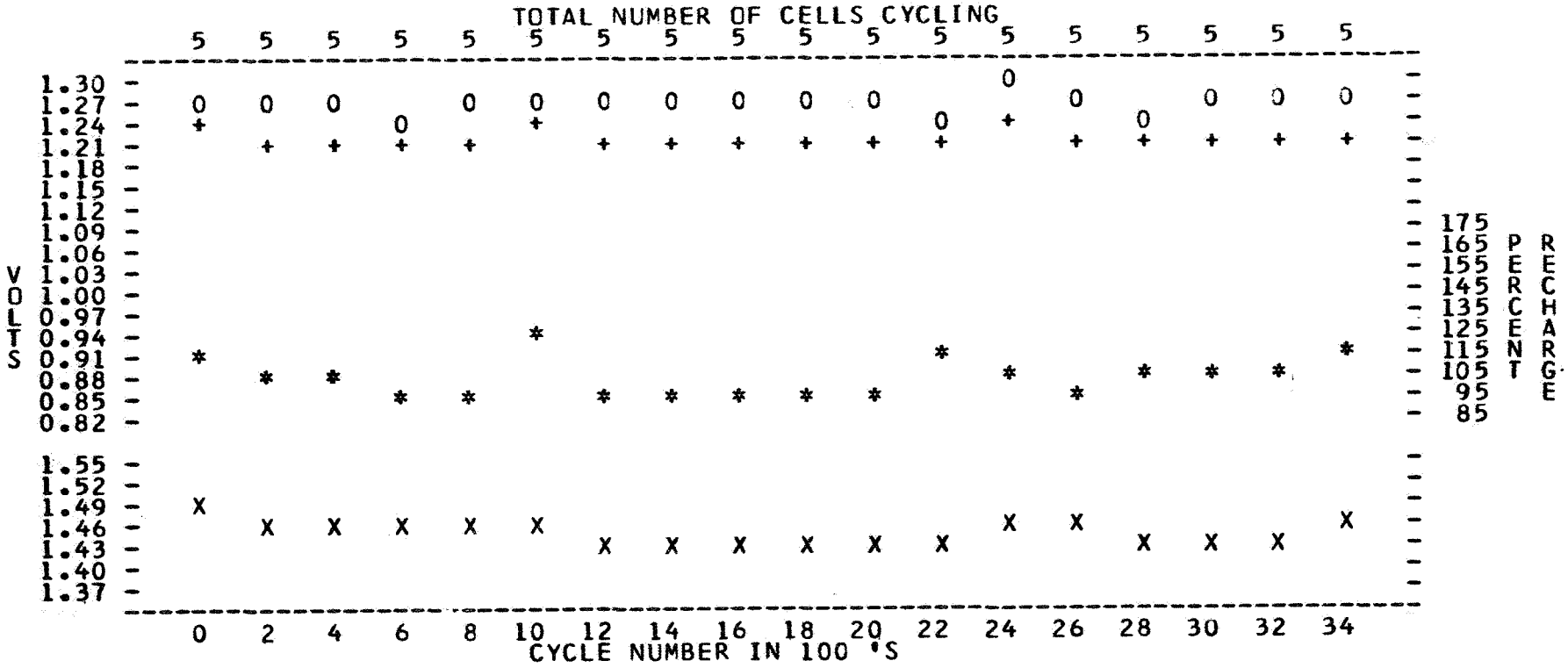
STATUS CELLS CYCLING 5
CYCLES COMPLETED 5695

CYCLE 3513 COULOMETER CHANGED. CYCLE 4306 COULOMETER CHANGED.

FIGURE 45(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 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.

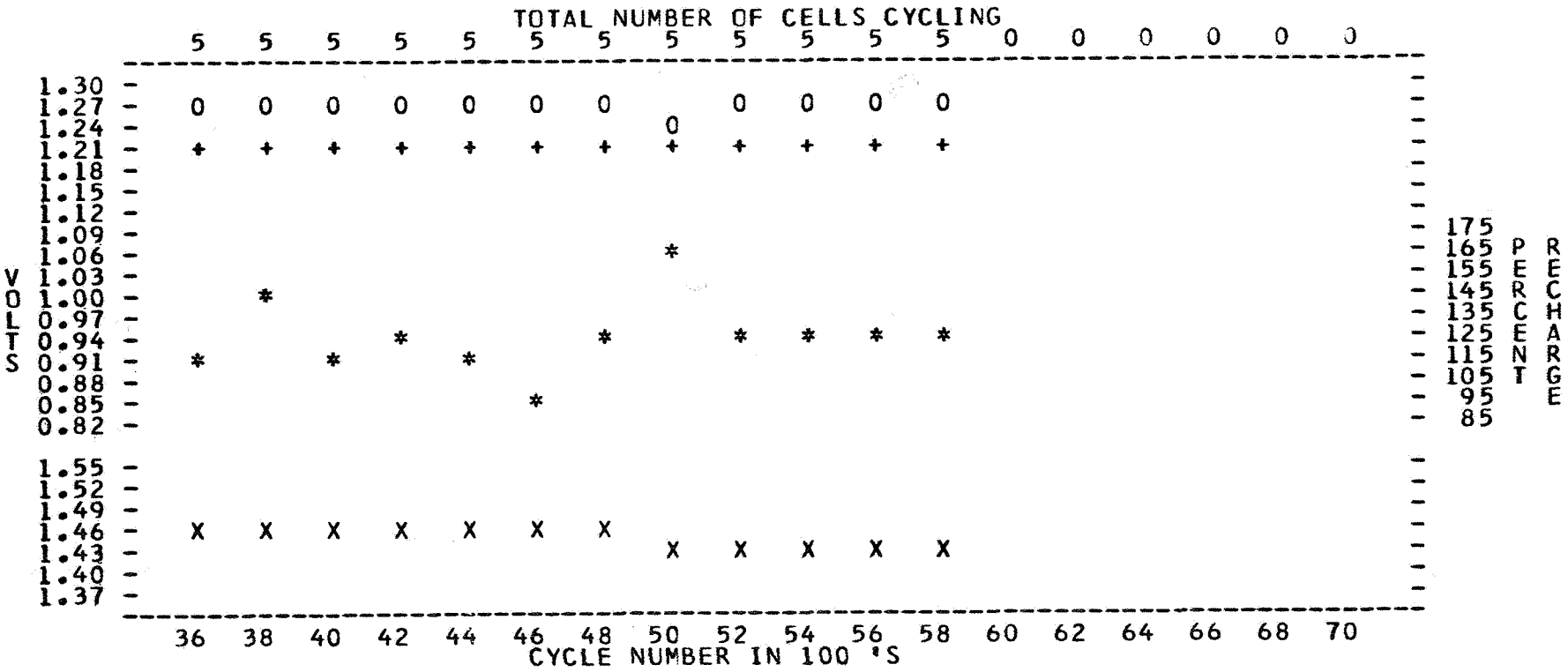
STATUS CELLS CYCLING 5
CYCLES COMPLETED 5898

CAPACITY CHECK CYCLES
920, 1808, 2497, 3146, 3891
4556, 5261,

CYCLE 729: COULOMETER FAILED: CYCLE 776: PUT NEW COULOMETER IN

FIGURE 45(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. 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.

STATUS CELLS CYCLING 5
CYCLES COMPLETED 5898

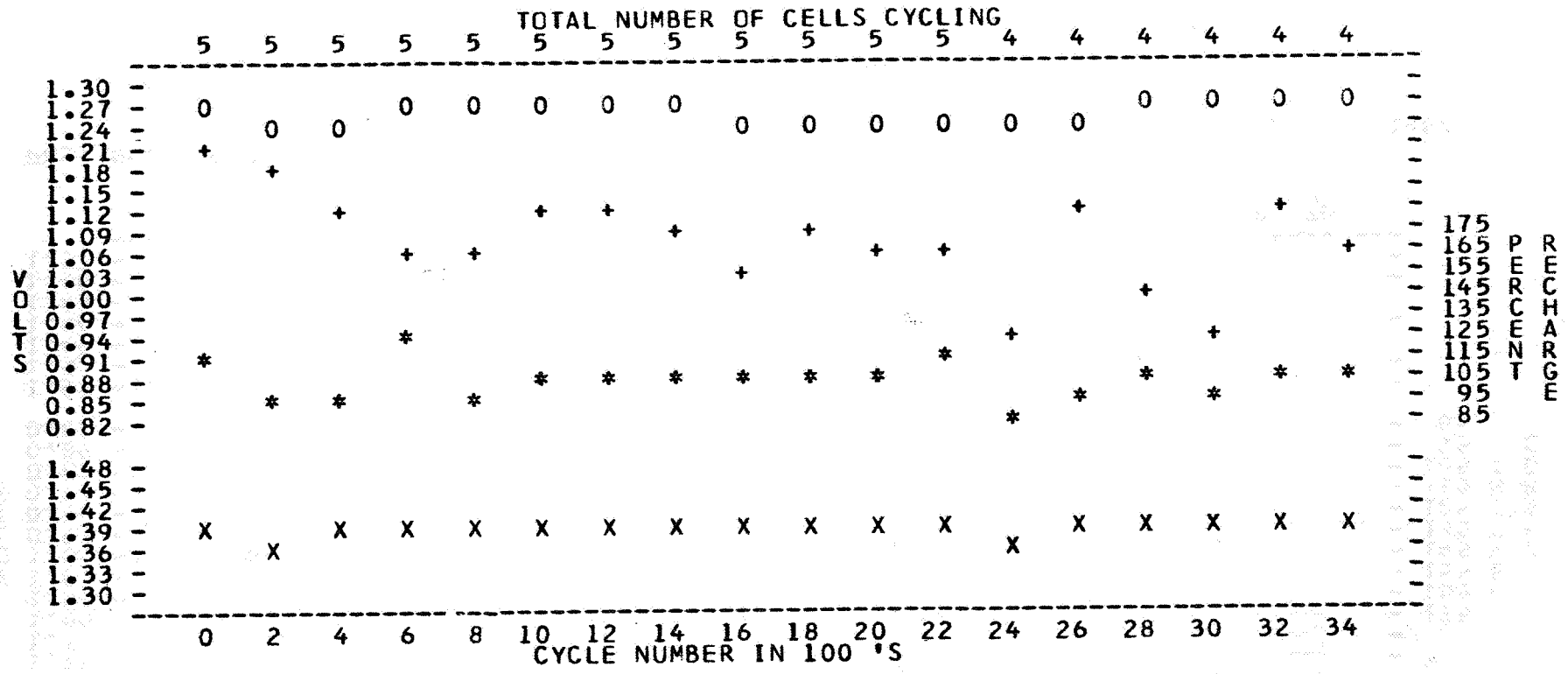
CAPACITY CHECK CYCLES
920, 1808, 2497, 3146, 3891
4556, 5261,

CYCLE 729: COULOMETER FAILED: CYCLE 776: PUT NEW COULOMETER IN

FIGURE 45(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. 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.

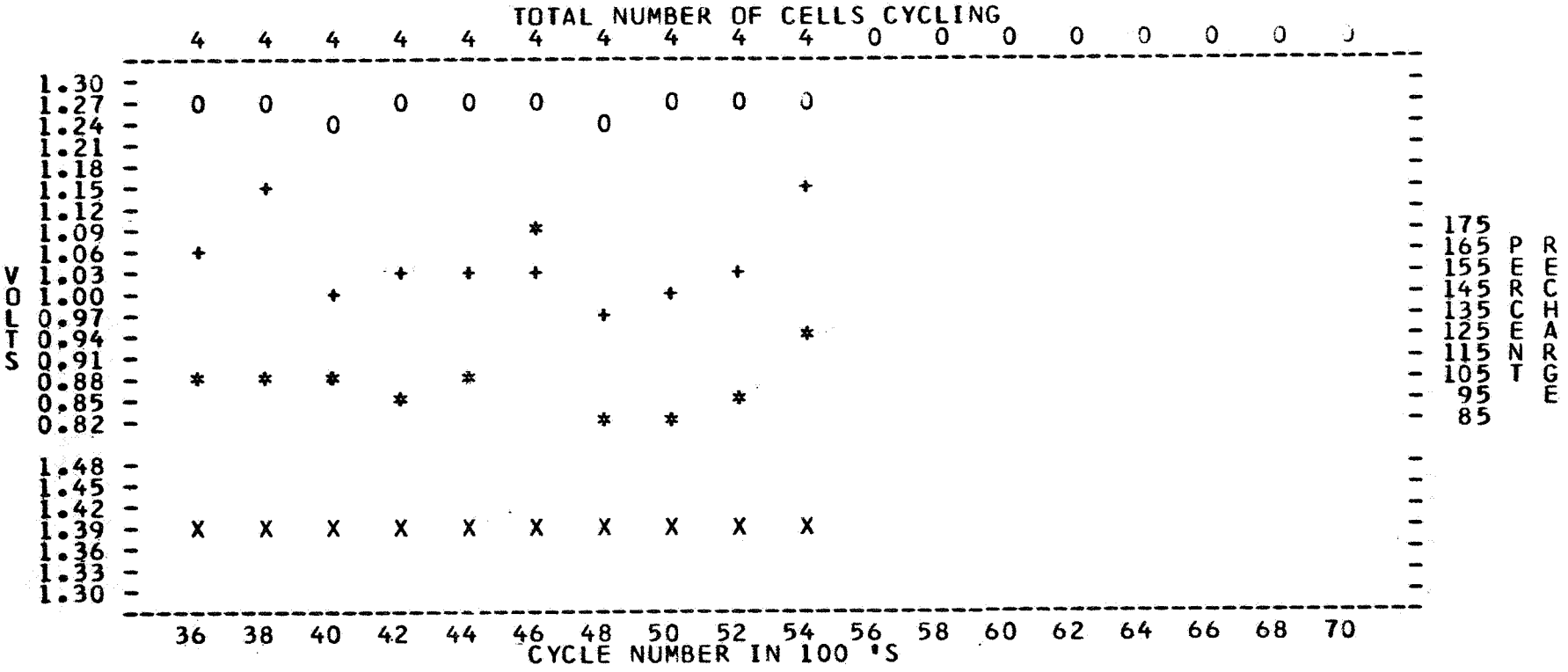
STATUS CELLS CYCLING 5
CYCLES COMPLETED 5465

CAPACITY CHECK CYCLES
920, 1784, 1833, 2400, 3008
3722, 4919, 5108,

FIGURE 45(C)

QE/C 69-244

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

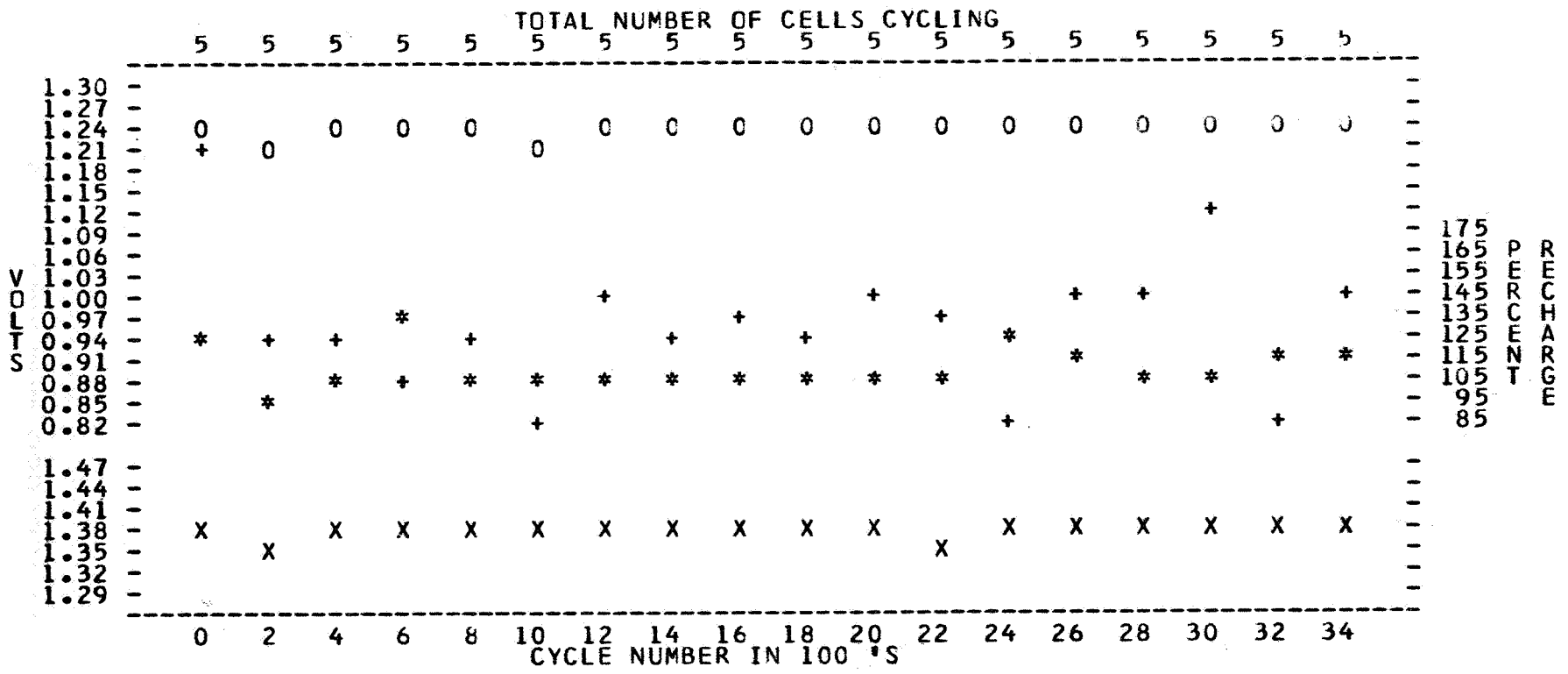
PACK NUMBER 018C
TYPE OF CELLS GULTON 6.00 AH
TEST TEMPERATURE 25 DEGREES C.
ORBIT PERIOD 03.0 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 3.00 AMP.

STATUS CELLS CYCLING 5
CYCLES COMPLETED 5465

CAPACITY CHECK CYCLES
920, 1784, 1833, 2400, 3008
3722, 4919, 5108,

FIGURE 45(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



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.

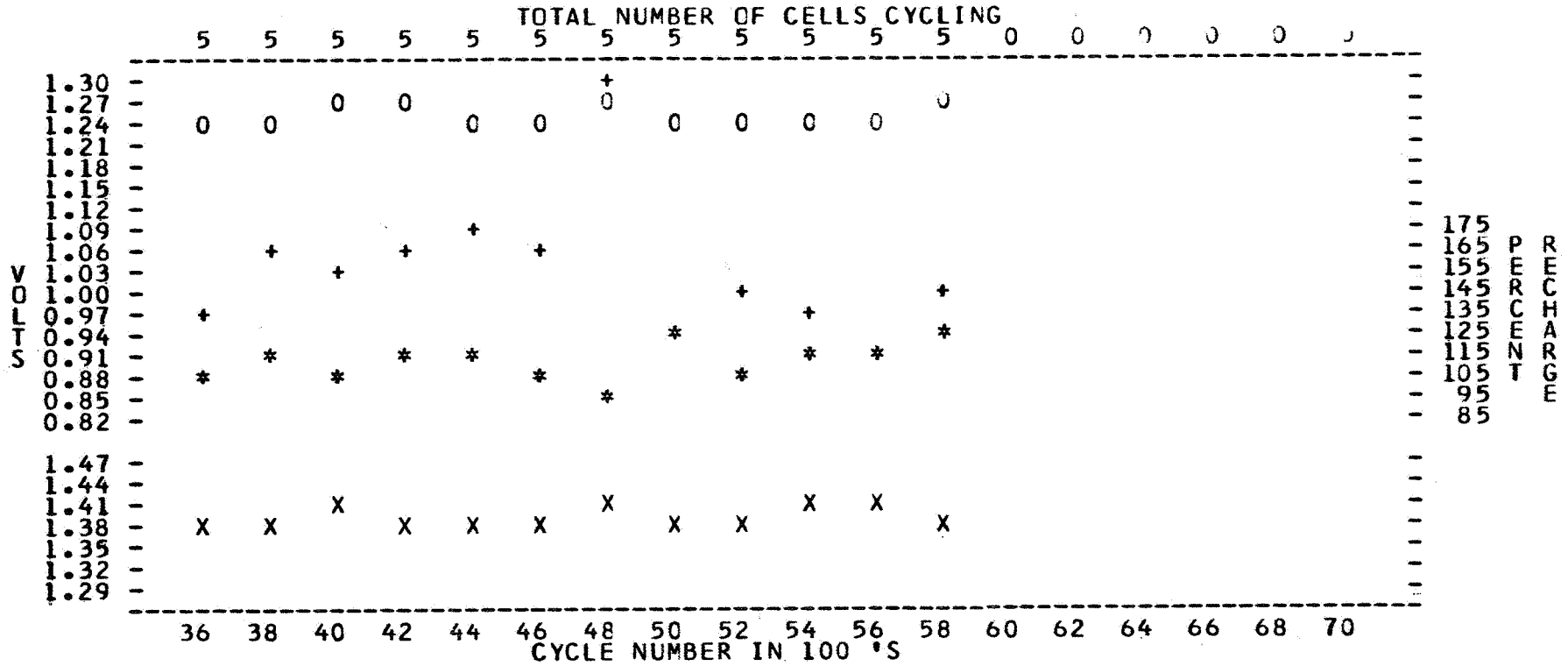
STATUS CELLS CYCLING 5
CYCLES COMPLETED 5833

CAPACITY CHECK CYCLES
894, 1721, 2393, 3081, 3786
4491, 5196,

CYCLE 264 TRICKLE CHARGE SET 250 MA.

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



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, 3081, 3786
4491, 5196,

STATUS CELLS CYCLING 5
CYCLES COMPLETED 5833

CYCLE 264 TRICKLE CHARGE SET 250 MA.

FIGURE 45(D) (CONTD)

4. Sonotone 5.0 ah, One 5-cell Pack, 1.5-hour Orbit Period:

a. Cell Description:

(1) The cells used were of the type described in Section I, Paragraph I.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 currents are supplied by a unit described in Section I, Paragraph IV.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) Lower 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) Lower 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: 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.

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 currents are 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. Cells 1 through 5 in each pack are standard cells; cells 6 through 10 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: (Figures 46(A) through 46(D).) Shortly after start of cycling in September 1967, all cells developed high internal pressure. The cases of all cells became distorted, four of which ruptured, resulting in a total of 14 cell failures. Cycling was halted in November 1967 at the request of the manufacturer's representative. Up to this time, Packs 10A, 22A, 34B, 46A and 72B completed 1170, 599, 943, 427 and 609 cycles respectively.

(a) The situation was reviewed with a representative from NASA, Lewis Research Center, and one from the manufacturer in order to evaluate the results and to determine steps to be taken for continuation of the cycling test. Following failure analysis of five of the 14 cells at NAD Crane, the manufacturer's representative took the remaining nine failed cells with him for testing to determine the cause for excessive pressure buildup in both the control and spring loaded cells.

(b) After completion of his testing, the manufacturer made the following recommendations:

1. Install new relief valves.

2. Recondition remaining 36 cells, and reduce charge currents of Packs 22A, 34B and 46A from 20 to 15 amperes.

(c) Following completion of these recommendations, four of the five packs were returned to automatic cycling in September 1968. Cycling of Pack 72B was delayed until early 1969. Packs 10A, 22A, 34B and 46A have completed 1545, 1597, 1597 and 798 additional cycles to date with no cell failures. The total number of cycles completed to date is 2715 for Pack 10A, 2196 for Pack 22A, 2540 for Pack 34B, and 1225 cycles for Pack 46A.

(2) Cell failures during first cycling period and charge current changes:

(a) Pack 10A had no cell failures. The charging current was left at 7.0 amperes.

(b) Pack 22A: Six cells failed, three of which were conventional and three were spring loaded. Each cell became internally shorted as a result of distortion of the container, causing it to come in contact with the positive and negative plates. One of the spring loaded cells was ruptured. The charge current was reduced from 20 to 15 amperes for the second period of cycling.

(c) Pack 34B: Three cells failed, two of which were conventional and one was spring loaded. Each cell became internally shorted as a result of distortion of the container, causing it to come in contact with the positive and negative plates. One of each type of cell was ruptured. The charge current was reduced from 20 to 15 amperes for the second period of cycling.

(d) Pack 46A: Five cells failed, one of which was conventional and four were spring loaded. Each cell became

internally shorted as a result of distortion of the container causing it to come in contact with the positive and negative plates. One of the spring loaded cells ruptured.

(e) Pack 72B had no cell failures. The charge current was left at 20 amperes since the percent depth of discharge required that charging rate.

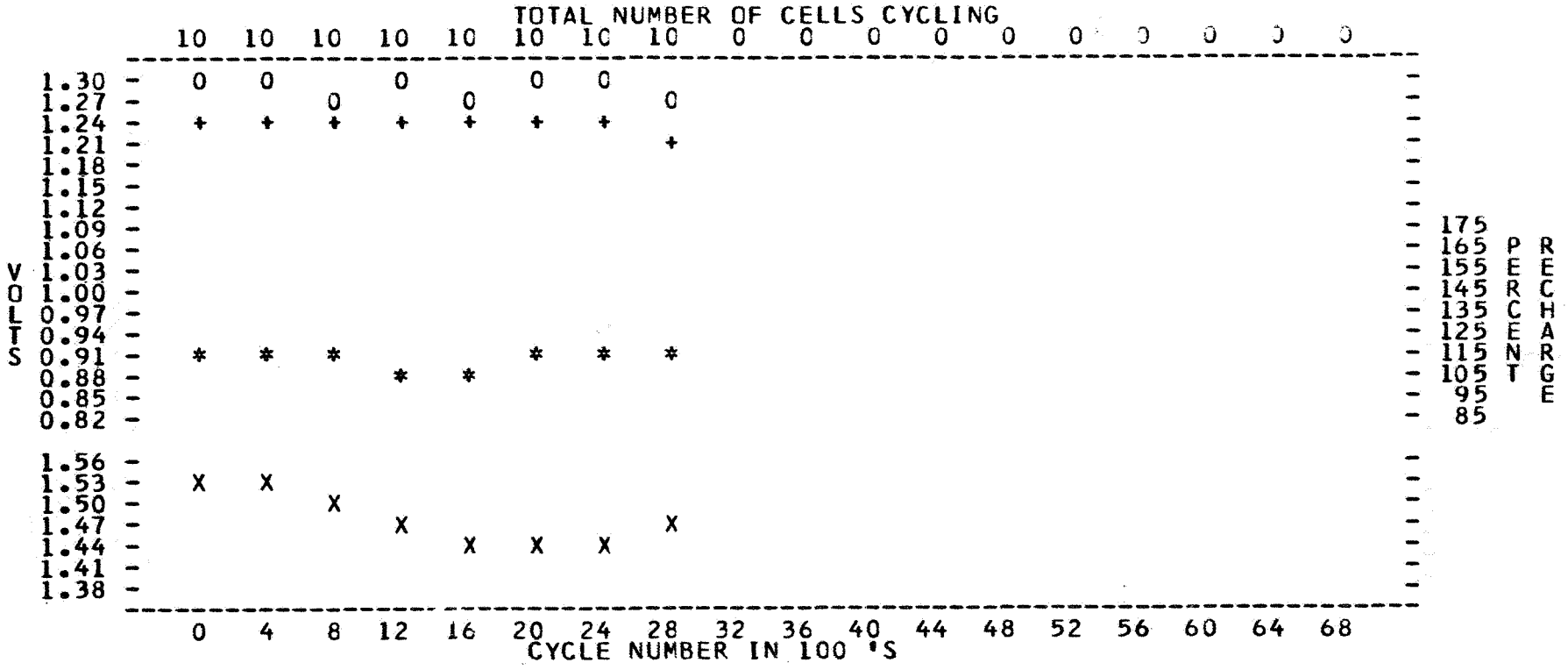
(3) Capacity checks: The ampere-hour capacities on the precycling capacity check cycles are as follows:

PRECYCLING

Orbit Period (Hr)	1.5	1.5	3.0	1.5
Temperature	25°	25°	25°	25°
Depth of Discharge	25%	25%	40%	75%
Pack Number	10A	22A	46A	72B
Precycling Capacity	28.7	28.8	25.7	26.2

GE/C 69-244

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 010A
TYPE OF CELLS SONOTONE 20.00 AH
TEST TEMPERATURE 25 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 7.00 AMP.

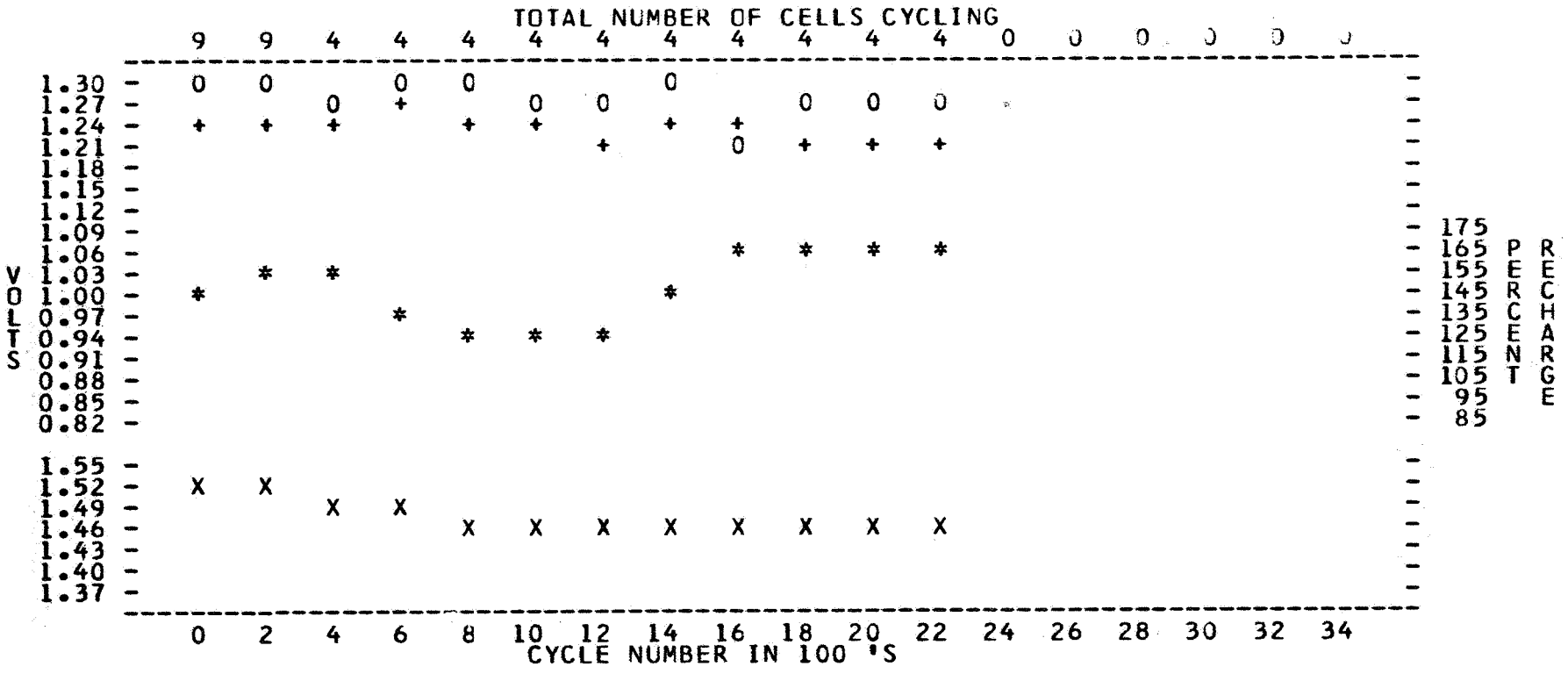
CAPACITY CHECK CYCLES
0,

STATUS CELLS CYCLING 10
CYCLES COMPLETED 2715

OFF 11-27-67 TO 9-02-68 RECONDITIONING.

FIGURE 46(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
10	49
04	541
05	541
09	541
03	541

PACK NUMBER 022A
TYPE OF CELLS SONOTONE 20.00 AH
TEST TEMPERATURE 25 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 20.00 AMP.

CAPACITY CHECK CYCLES
0,

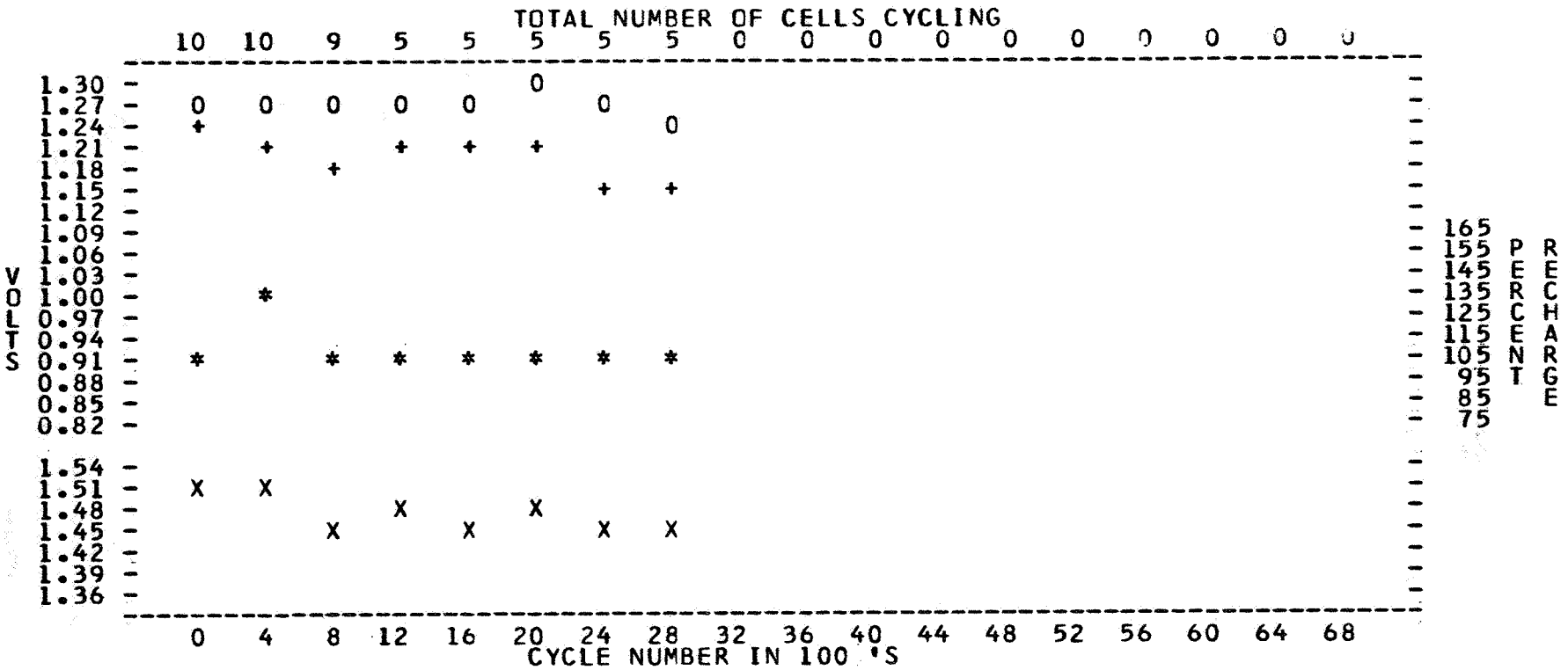
STATUS CELLS CYCLING 5
CYCLES COMPLETED 2196

OFF 11-29-67 TO 9-02-68 RECONDITIONING.

FIGURE 46(B)

QE/C 69-244

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
08	512
02	877
03	877

PACK NUMBER 034B
TYPE OF CELLS SONOTONE 20.00 AH
TEST TEMPERATURE 25 DEGREES C.
ORBIT PERIOD 01.5 HOURS
DEPTH OF DISCHARGE 40 PERCENT
SPECIFIED CHARGE RATE 20.00 AMP.

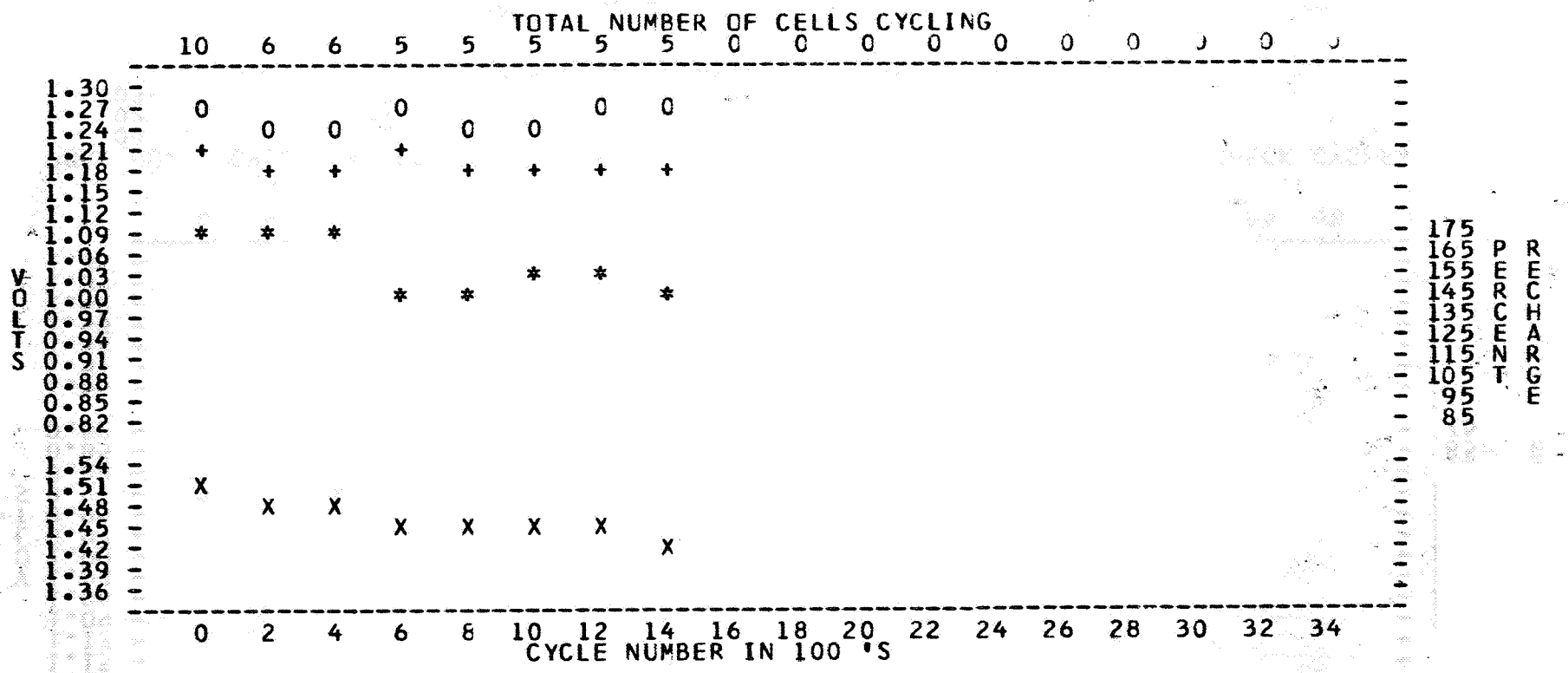
CAPACITY CHECK CYCLES
0,

STATUS CELLS CYCLING 7
CYCLES COMPLETED 2540

OFF 11-29-67 TO 9-02-68 RECONDITIONING

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



POS. NO.	CYCLE FAILED
07	153
09	153
02	393
06	393
10	393

PACK NUMBER 046A
TYPE OF CELLS SONOTONE 20.00 AH
TEST TEMPERATURE 40 DEGREES C.
ORBIT PERIOD 03.0 HOURS
DEPTH OF DISCHARGE 25 PERCENT
SPECIFIED CHARGE RATE 20.00 AMP.

CAPACITY CHECK CYCLES
0,

STATUS CELLS CYCLING 5
CYCLES COMPLETED 1225

OFF 11-29-67 TO 9-02-68 RECONDITIONING

FIGURE 46(D)

III. TESTS TO BE ADDED TO THE CYCLE LIFE TEST PROGRAM

A. Nickel-Cadmium:

1. Gulton 6.0 ampere-hour cells with controlled amounts of electrolyte.

2. Gulton 6.0 ampere-hour cells for evaluation under Test and Training Satellite (TETR) parameters.

3. Gulton 20 ampere-hour cells with controlled amounts of precharge on the negative plates.

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