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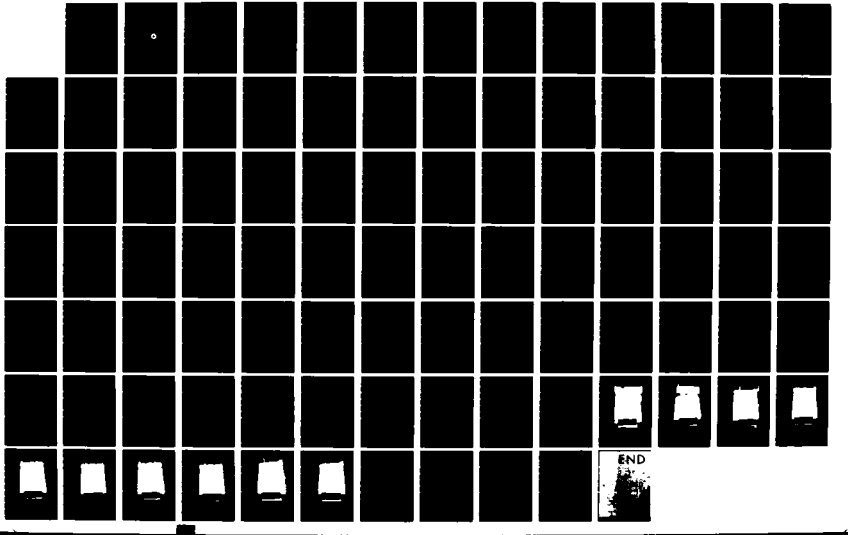

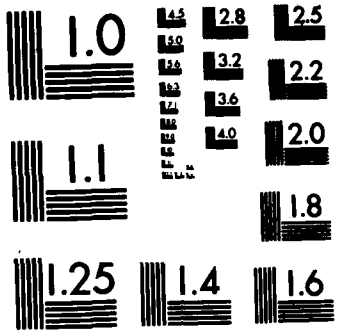

Report No. CG-D-56-82

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PERFORMANCE CHARACTERISTICS OF FIVE CANDIDATE SECONDARY BATTERIES FOR PHOTOVOLTAIC POWER SYSTEMS

PREPARED BY

WEAPONS QUALITY ENGINEERING CENTER

NAVAL WEAPONS SUPPORT CENTER, CRANE, INDIANA

FINAL REPORT

MARCH 1983

prepared for

U.S. DEPARTMENT OF TRANSPORTATION
United States Coast Guard
Office of Research and Development
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16. Abstract

This document provides the Coast Guard with the results of baseline capacity, overcharge, and state-of-charge tests conducted on five candidate secondary batteries for photovoltaic power systems. Three candidate batteries (DELCO-REMY, GLOBE UNION, and J. C. PENNY) were sealed, low maintenance type lead-acid batteries with lead-calcium grids. The fourth candidate (ESB WILLARD) was a vented charge retaining lead-acid battery constructed with high purity thick lead grids. The fifth candidate secondary battery was a pocket plate type nickel-cadmium battery (NIFE). Tests were also performed on cycled ESB-WILLARD batteries that had been operated seven years in solar photovoltaic power systems.

Equilibrium voltage measurements at two temperatures (-20C, 50C) for various charge rates at 80, 90 and 100% state-of-charge were completed on all batteries. This information can be used to set voltage regulation points and temperature compensation coefficients for each battery.

Failure analysis of the batteries cycled seven years in photovoltaic power systems revealed moderate sulfation of the negative plates and a moderate amount of sediment in the bottom of the battery case. Three to five additional years of cycling is estimated for these batteries.

The nickel-cadmium batteries do not appear to be suitable for this application due to their low charge efficiency at low charge rates.

The lead-calcium grid batteries have similar electrical characteristics to the pure-lead grid batteries. Further testing is necessary to evaluate if their operational life would be comparable to the pure-lead charge retaining batteries in photovoltaic power systems.

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UNCLASSIFIED	UNCLASSIFIED	93	

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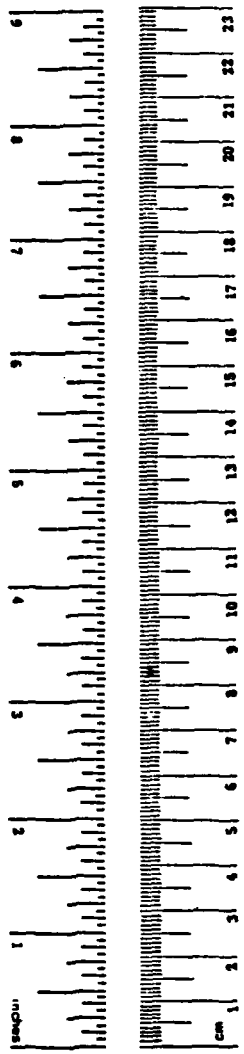
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

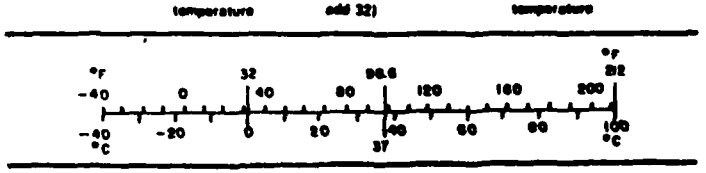
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



FINAL REPORT
OF
PERFORMANCE CHARACTERISTICS OF FIVE CANDIDATE SECONDARY BATTERIES FOR PHOTOVOLTAIC POWER SYSTEMS

Prepared for:
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Washington, DC 20593

Prepared by:
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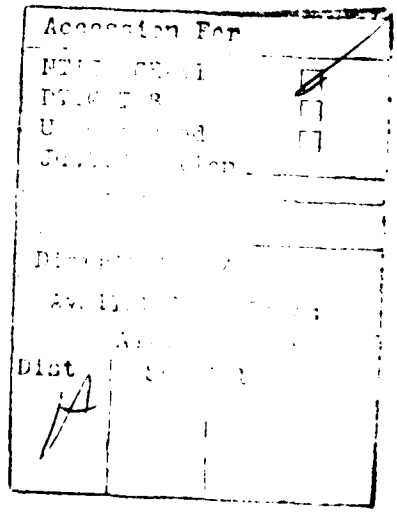

Under
MIPR Z70099-1-01422

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Report Brief
Performance Characteristics of Five Candidate Secondary Batteries for Photovoltaic Power Systems

Ref: (a) U. S. Coast Guard MIPR Z 70099-1-01422

I. TASK ASSIGNMENT

A. Conduct a test program to obtain the performance characteristics of one type or model of secondary battery from each of five different manufacturers. These battery types, as selected by the U. S. Coast Guard, were subjected to test parameters simulating conditions the batteries may be subjected to if deployed in an aid to navigation. Therefore, the performance characteristics obtained will identify those batteries which are suitable for use with photovoltaic power systems. Testing was conducted and funded under the conditions as outlined by reference (a).

B. Lead-acid type batteries from four manufacturers; Delco-Remy, Globe Union, J. C. Penney (manufactured by Gould or Delco), and ESB (Willard); were purchased and evaluated on the test program. Also, evaluation of cycled Willard type batteries, that were received from the U. S. Coast Guard's Research and Development Center in Groton, Connecticut, which had previously been operated for seven years in a photovoltaic power system, were evaluated to compare their performance with new batteries of the same type.

C. A nickel-cadmium pocket type battery, manufactured by NIFE, was also evaluated on the test program.

D. A total of 18 batteries, three of each type, were subjected to baseline capacity, overcharge and state-of-charge tests.

II. CONCLUSIONS

A. Capacity determination testing is a means for evaluating a manufacturer's quality control in production of his batteries.

B. The state-of-charge of a battery can be determined by knowing its temperature, voltage, and charge current, and then applying this information to its proper performance characteristic curves.

C. Lead-acid type batteries:

1. A minimum of eighty percent of rated capacity can be expected to be obtained using low charge and discharge rates (Cm/100) at 20°C, regardless of how the manufacturer rates his batteries.

2. Expect a capacity loss of 35 to 70 percent at the -20°C temperature and an increase of 5 to 30 percent at the 50°C temperature.

3. Equilibrium battery voltages vary between the different types of batteries with those voltages at -20°C being from .7 to 1.2 volts higher than those at 50°C.

4. Water loss is significant at the C/67 to C/33 charge rates when the batteries are being overcharged and the loss at 50°C is slightly more than that at -20°C.

5. Although only the Willard type batteries could be compared, it is expected that only slight differences would occur in the performance characteristics between new and cycled (over 5-years life) batteries if the batteries were designed for operation in a photovoltaic power system similar to that proposed by the U. S. Coast Guard.

D. Nickel-cadimum pocket type batteries:

1. A Cm/100 charge rate is not efficient for these type batteries in that only 80 to 85 percent of rated capacity can be expected to be delivered at 20°C. An increase in the charge rate to a minimum of Cm/20 should result in 100 percent of rated capacity delivered. To incorporate a nickel-cadmium battery into a photovoltaic power system requires a basic change in the present design philosophy. In order to overcome the batteries low charge efficiency at low charge rates, the solar array current output would have to be greatly increased relative to the battery capacity to increase the charge rate to a region where the nickel-cadmium battery efficiently accepts charge. A hypothetical power system with a nickel-cadmium battery would be configured with a 10 ampere-hour battery and a 50 to 100 watt solar array vice the present design of a 10 watt array with a 100 ampere-hour lead-calcium battery. This hypothetical system would not have the large capacity reserve of the present design and would also be more expensive. A large reduction in the price of solar arrays would improve the economics of a nickel-cadmium photovoltaic power system.

2. Expect minimum loss of capacity at -20°C and although the capacity test at 50°C also showed minimum loss at this temperature, it can be expected that a 50°C operating temperature will greatly reduce the life of these batteries whereas a 0°C to 10°C will result in maximum life.

3. Battery voltages, when fully charged, are approximately 2.5 volts higher at -20°C than at 50°C.

4. Weight loss is minimum at both the -20°C and 50°C test temperatures.

III. RECOMMENDATIONS

A. Lead-acid type batteries should be deployed in photovoltaic power systems with emphasis placed on those batteries designed for this type of operation. Various types of lead-calcium grid batteries, which are readily available from a national retail outlet, are electrically compatible with a photovoltaic power system. However, further testing is necessary to evaluate their life expectancy.

B. Capacity determination tests should be performed on all batteries placed in service. These tests may be reduced to battery lot testing if a high confidence level is achieved.

C. Charge efficiency curves, for candidate batteries, should be generated using various low charge/discharge rates that the batteries would be subjected to in a photovoltaic power system.

D. Efforts should be continued to keep abreast of new advancements in battery technology in that continuing efforts are being pursued by the battery manufacturers to improve their products. One example is a new lead-acid battery (Cathanode) and is manufactured by GNB Batteries, a division of Gould, Inc. This battery is intended for automotive use, however, it may prove feasible for photovoltaic applications. It is advertized to deliver 40 percent more energy than other lead-acid batteries of comparable dimensions. The cost is approximately $90 and is available at national outlet stores.

Final Report of Performance Characteristics of Five Candidate Secondary Batteries for Photovoltaic Power Systems

I. INTRODUCTION

A. A major mission of the U. S. Coast Guard is the task of establishing and maintaining maritime aids to navigation. Specific aids are located along the coastline and waterways of the United States and its possessions.

1. Approximately 14,000 of the approximately 50,000 aids now being maintained provide a light signal at night. Most of these signals are powered by air-depolarized primary batteries whose source life is one to three years.

2. The most significant battery cost involved with the existing system is having a ship and crew frequent the aid site due to battery problems. Also, battery replacement costs and the disposition of expended batteries are major cost items.

B. For the last several years, the Coast Guard has been involved with developing a solar photovoltaic power system with secondary batteries to power these lighted aids. Work has progressed to the point where approximately 1200 of these aids should be converted to photovoltaic power during the next two years.

C. An optimum secondary type battery for a photovoltaic power system would accept charge efficiently, withstand overcharge currents without damage or significant water loss, and have a moderate life expectancy (4 to 6 years). Logistically, it would be an advantage for the Coast Guard if the battery were available at national retail outlet stores. This would reduce warehouse facilities and facilitate exchange of depleted batteries, thereby reducing overhead expense.

1. The Naval Weapons Support Center, Crane, Indiana conducted a test program (Appendix A) to obtain the performance characteristics of one type or model of secondary battery from each of five different manufacturers. The test parameters were selected to subject the batteries to conditions which they may experience if deployed in an aid to navigation, thereby allowing the U. S. Coast Guard to identify those batteries whose performance characteristics are suitable for use with photovoltaic power systems.

2. A total of 15 new batteries and previously cycled batteries were subjected to: (a) Baseline Capacity Tests to determine the batteries actual capacity, 20°C, (b) Overcharge Tests to determine the batteries equilibrium voltage at six different charge rates both at the -20°C and 50°C test temperatures, and (c) State-Of-Charge characteristics at the 90 and 80 percent levels for six charge rates both at the -20°C and 50°C test temperatures.

3. Testing began 8 October 1981 and ended 17 September 1982.

II. TEST BATTERY SAMPLES

A. Three batteries of each type/model were subjected to the test program. They were wired in series avoiding any series/parallel configurations. The batteries purchased from the five manufactureres, as were selected by the U. S. Coast Guard, were:

Willard	Model DD-3-3
Willard (Cycled)	Model DD-3-3
Delco-Remy	Model 2000
J. C. Penney	Survivior 72
Globe Union	GC 12550-3A
NIFE	L-302-2

1. The Willard batteries were 6-volt lead-acid type batteries with a manufacturer's rating of 100 ampere-hours and P/N 8241. The cycled batteries had 7 years operation in a photovoltaic power system at the U. S. Coast Guard's Research and Development Center in Groton, Connecticut. These batteries wer tested to compare characteristics with new batteries of this type. The battery is rectangular and has the automobile type terminal post. The battery is unsealed, although purchased with spill proof vents, in that electrolyte levels may be adjusted. The manufacturer classifies this as a charge retaining battery, but it has the same basic components and electrochemical reactions as the standard lead-acid battery. The charge retaining battery components are constructed of high-purity materials (lead grids) with thick positive and negative pl[illegible]s.

2. The Delco-Remy batteries were rectangular 12-volt lead-acid type batteries with a manufacturers rating of 96 ampere-hours. The batteries have lead-calcium alloy grids, are maintenance free, were sealed with pressure relief valves, and have the automobile type terminal posts. The manufacturer stated that this battery was designed for solar cell applications.

3. The J. C. Penney batteries were rectangular 12-volt lead-acid type batteries, with a manufacturers rating of 66 ampere-hours. The batteries have lead-calcium alloy grids, are maintenance free, were sealed with pressure relief valves, and have the automobile type terminal posts. These batteries are manufactured by Gould and Delco for J. C. Penney.

4. The Globe Union batteries (Type A) were rectangular 12-volt lead-acid type batteries with a manufacturer's rating of 55 ampere-hours. The batteries have lead-calcium alloy grids, are maintenance free having gelled electrolyte, were sealed with pressure relief valves, and have the automobile type terminal posts. There are two types of these batteries, types A and B, in which the manufacturer states that the type A is most suited for the U. S. Coast Guard's application.

5. The NIFE "batteries" consisted of ten, 1.2 volt nickel-cadmium pocket type cells connected in series to obtain a 12 volt battery with a manufacturer's rating of 66 ampere-hours. The cell cases were constructed of translucent polypropylene plastic with flame arresting flip top vents and the electrolyte (alkaline) level in the cells are adjusable. The cells have screw-type terminal posts.

III. TEST PROGRAM

A. Baseline Capacity Determination Tests - To determine the batteries' actual capacity when subjected to three low rate (Cm/100) charges and discharges, at a test temperature of 20°C, in which Cm = the manufacturer's rated capacity, no matter how the battery was rated. Cut-off values on discharge were 5.25 and 10.50 volts for the 6 and 12 volt batteries, respectively. Manufacturing quality control would also be indicated by the variance in capacity for each manufacturer's batteries. The results of these tests are contained in Table I.

1. General observations during these tests were:

(a) The J. C. Penney and Globe Union batteries delivered 106.5 percent and 104.7 percent of rated capacity, respectively, during their third capacity test. The Delco-Remy batteries delivered 97.3 percent and the other type batteries delivered from 82 to 85 percent.

(b) Battery capacity variance was very slight for each manufacturer's type batteries except the Willard's where the capacity of the new batteries ranged from 74.6 to 88.7 ampere-hours and the cycled batteries ranged from 80.6 to 89.6 ampere-hours.

(c) The capacity of the NIFE batteries dropped with each capacity test performed; but this is not unusual for new nickel-cadmium batteries when they are first placed into operation.

2. The value C referred to in the overcharge and state-of-charge evaluation tests was the average capacity value of each manufacturer's batteries as obtained during their last baseline capacity test.

B. Overcharge Evaluation Tests - To determine the batteries overcharge characteristics at six different charge rates which were C/33, C/40, C/50, C/67, C/100 and C/200. These characteristics were obtained at the -20°C and 50°C test temperatures.

1. The test procedure was such that the batteries were charged for 95 hours at their C/100 rate and then the charge current was increased to C/33 until the batteries reached equilibrium. The current was then reduced to the C/40 rate till equilibrium was reached and then repeated for the C/50, C/67, C/100 and C/200 rates. Following test completion of the first two samples of batteries (Willard - new and cycled), the procedure was modified in that following equilibrium at the C/200 rate, the test was repeated by reversing the order of the charge rates by going to C/100 back up to C/33. The purpose of this test change was to note if there were any significant changes in a batteries equilibrium voltage, when going from a high rate to a low rate charge and vice-versa. Only the J. C. Penney and Globe Union type batteries were subjected to this test modification as it did not have a significant effect on their equilibrium voltages.

TABLE I

CAPACITY TEST DATA

Battery Type	Capacity* Test #	Temp. (°C)	Discharge** Rate	CM or C	Capacity (Ampere-Hours) Battery #1	Battery #2	Battery #3	Average
Willard (New)	1	20	Cm/100	100	77.2	84.0	89.5	83.6
	2	20	Cm/100	100	74.3	85.6	88.4	82.8
	3	20	Cm/100	100	74.6	82.7	88.7	82.0
Willard (Cycled)	1	20	Cm/100	100	79.6	75.3	91.2	82.0
	2	20	Cm/100	100	82.1	77.6	89.9	83.2
	3	20	Cm/100	100	84.7	80.6	89.6	85.0
Delco-Remy	1	20	Cm/100	96	96.4	95.6	93.1	95.0
	2	20	Cm/100	96	94.7	94.7	92.3	93.9
	3	20	Cm/100	96	94.3	94.0	91.9	93.4
	4	-20	C/100	93	29.5	28.5	29.7	29.2
	5	50	C/100	93	122.6	108.9	122.1	117.9
J. C. Penney	1	20	Cm/100	66	60.9	61.3	67.9	63.4
	2	20	Cm/100	66	73.1	67.7	65.7	68.8
	3	20	Cm/100	66	69.2	70.6	71.0	70.3
	4	-20	C/100	70	42.3	46.3	44.7	44.4
	5	50	C/100	70	87.5	85.2	81.9	84.9
Globe Union	1	20	Cm/100	55	57.0	57.9	57.3	57.4
	2	20	Cm/100	55	57.8	57.1	57.3	57.4
	3	20	Cm/100	55	57.9	57.0	57.8	57.6
	4	-20	C/100	58	34.2	35.2	35.0	34.8
	5	50	C/100	58	59.9	63.7	62.2	61.9
NIFE	1	20	Cm/100	66	68.5	69.3	66.8	68.2
	2	20	Cm/100	66	62.4	64.1	57.4	61.3
	3	20	Cm/100	66	55.8	54.9	54.7	55.1
	4	-20	C/100	55	52.3	53.3	51.3	52.3
	5	50	C/100	55	49.1	48.6	51.8	49.8

* Tests 1, 2, and 3 were the base line tests; tests 4 and 5 were performed following the state-of-charge tests at the indicated temperatures. The Willard batteries were not subjected to tests 4 and 5 as they completed test prior to the change in the test procedure which first incorporated these tests.

**Cm is the manufacturer's rated capacity and C is the battery types average mean capacity.

2. General observations during these tests were:

(a) Equilibrium voltages at -20°C were higher than those at 50°C with the range being .7 to 1.2 volts for the lead-acid type batteries and 2.5 volts for the nickel-cadmium batteries.

(b) Calculation of the standard deviation values, showed that during the -20°C tests, the greatest battery voltage variations were exhibited by the Willard (Cycled) batteries at the C/100 and C/200 charge rates, and the J. C. Penney batteries at each of the six charge rates. The Willard (Cycled) batteries, C/40 to C/200 charge rates, and the Globe Union batteries, C/67 to C/200 charge rates, exhibited the most variation during the 50°C tests. Minimum variations during these tests were shown by the new Willard batteries at -20°C and the Delco-Remy and NIFE batteries at 50°C.

(c) Equilibrium voltages of the new Willard batteries were .2 to .6 volts higher than those which had previously been cycled for 7 years. This shows that the end-of-charge voltages of pure lead batteries do decrease as their life progresses.

(d) The J. C. Penney, Globe Union, Delco-Remy and NIFE batteries took a minimum of 18 hours to reach equilibrium at the C/33 rate at 50°C.

(e) Electrolyte leakage, at the pressure relief valves, of one of the J. C. Penney batteries' occurred during the 50°C tests.

(f) Weight loss, as a measure of a battery's water consumption by evaporation and electrolysis, was greatest when overcharging at the C/33 rate. The overall weight loss during the 50°C tests was slightly more than the -20°C tests. The Delco-Remy batteries did exhibit the largest loss during these tests.

(g) There was no significant difference exhibited in weight loss between the two groups of Willard batteries.

3. Equilibrium voltages and weight loss per hour for each charge rate, were plotted for each type of battery at -20°C and 50°C and are contained in Appendix B. Only the last three data points prior to changing the charge rate were plotted. The data from which these graphs were plotted is contained in Appendix C.

C. State-of-Charge Evaluation Tests - To determine the batteries state-of-charge-characteristics at the 90 and 80 percent levels, as generated by C/100 discharges for 10 and 20 hours, for charge rates of C/33, C/40, C/50, C/67, C/100 and C/200. These characteristics were obtained at the -20°C and 50°C test temperatures.

1. The procedure was such that the batteries were discharged at C/100 for 10 hours (corresponding to the 90 percent level), recharged at the C/33 rate until 100 percent of the capacity removed was returned and then placed on stand for 12 hours at which time the sequence would begin again except using the next charge rate. When the 90 percent level was completed for all six charge rates,

the sequence would start over except the discharge time would be 20 hours which corresponds to the 80 percent level. These tests began at the -20°C test temperature and when they were completed, the test was repeated at 50°C. Following test completion of the first two samples of batteries (Willard-new and cycled), the procedure was modified in that the recharge time was extended to provide a maximum of 175 percent return of the capacity removed or until the batteries reached equilibrium. Also, a capacity test was performed at -20°C and 50°C following completion of the state-of-charge tests at these temperatures.

2. This test was to provide information that would allow the Coast Guard to directly determine a batteries state-of-charge by knowing its voltage and charge rate at either -20°C or 50°C, providing the batteries state-of-charge was not less than 80 percent. Also, this data should provide the means to determine these states at other battery operating temperatures.

3. General observations during these tests were:

(a) The state-of-charge voltages of all the batteries were higher during the tests performed at -20°C than those at 50°C. Also, their end-of-discharge voltages were higher.

(b) Comparison of the two types of Willard batteries, new and cycled, showed that the state-of-charge voltages of the new batteries ranged from .11 to .25 volts higher during the -20°C tests and .08 to .12 volts higher during the 50°C tests.

(c) Erratic behavior was noted by one of the J. C. Penney batteries when it began its 50°C tests. Voltages of this battery were out of line with the other two batteries, of this type, and its voltage also fluctuated during the discharge and stand portions of the test. Leakage was noted at its pressure relief valves during this time.

(d) Water loss, as measured by weight change during these tests, occurred during charging as the batteries reached their equilibrium state. The Willard type batteries did not exhibit a significant loss during charge as they were not charged to an equilibrium state as these batteries completed test prior to the change in the test procedure which required the batteries to be charged to equilibrium or 175 percent return of the capacity removed.

4. Charge rate versus state-of-charge voltage plots for each test temperature are contained in Appendix D. It should be noted that the state-of-charge voltage values, which were plotted for the 80 and 90 percent curves, are those values obtained 2.4 minutes at the start-of-charge following each discharge. Values obtained during the overcharge evaluation tests were used for the 100 percent curves. Standard deviation values are also shown on these graphs. The data from which these graphs were plotted along with end-of-discharge, charge, and stand voltages, including water loss during these periods, is contained in Appendix E.

(a) Environmental chamber problems occurred prior to the C/50 rate recharge during the 80 percent state-of-charge test at -20°C. This affected the NIFE and Delco-Remy type batteries in that they had a stand period of 58 hours prior to their start-of-charge at the C/50 rate. This stand period caused a large fluctuation in the NIFE batterie's curve; but only resulted in a slight variation in the curve for the Delco-Remy batteries.

(b) Dotted lines were drawn on the graphs to represent expected values if hardware or battery variations hadn't occurred.

5. Results of the capacity tests performed on these batteries, except the Willard types, following their state-of-charge tests at each temperature were as follows:

1. The lead-acid type batteries showed a significant loss of capacity at -20°C with the Delco-Remy batteries delivering only 29 percent of actual capacity. The nickel-cadmium, NIFE batteries delivered 95 percent of actual capacity.

2. The NIFE cells delivered 90 percent of actual capacity at 50°C whereas all the lead-acid type batteries delivered in excess of their actual capacity. The Delco-Remy and J. C. Penney batteries delivered in excess of 120 percent and the Globe Union batteries delivered 107 percent.

D. Failure Analysis - Visual tear-down analysis was performed by Crane on four Willard batteries that had 7 years operation in a photovoltaic power system at the U. S. Coast Guard's Research and Development Center in Groton, Connecticut. The batteries were identified as U1A, U1B, U2A and U2B by Groton and U1A and U1B were cycled there as a 12-volt battery as was U2A and U2B. Batteries U1A, U1B, and U2A were subjected to this test program and were designated as the Willard (Cycled) type batteries, 1, 2, and 3 respectively.

1. Shedding of the positive plate active material was evident in all the batteries with approximately 1/2 inch of sediment in the bottom of the cell jars. This was approximately half of the allowed available space for sediment before shorting would occur. The negative plates of the batteries were sulfated with the sulfation of U2 batteries being slight when compared with the other two. Corrosion was noted on the positive terminals of each battery and slight corrosion of the negative terminals of the U2 batteries. The case sealant of each battery was cracked and the U2 batteries had slight hot spots located in their separators below their fill ports in the cells which were tore open. These spots may have been caused by a thermometer being pushed down into the separator prior to testing at Crane. Battery U1A had a glass mat adhere to its positive plate. The negative plates and grids of each battery were in good condition with no loss of active material. Based on these results, three to five additional years of cycling is estimated for these batteries before failure would occur.

2. Analysis results, including photographs, are contained in Appendix F which indicates the condition of those items listed.

IV. DATA MANAGEMENT

A. During these tests, the Automatic Data Acquisition and Control System (ADACS), described in Appendix G, was programmed to record the data at the start and end of discharge, charge and stand periods, and at 1-hour intervals during the Baseline tests, 15-minute intervals during the overcharge tests, and 30-minute intervals during the state-of-charge tests. Periodically, this data was sorted and merged so that data of each test for that period of time would be together.

1. There were approximately 25,200 records written on raw data tapes that have been reduced to 9 master tapes.

2. The data is contained on 9 track, EBCDIC, 1600 bpi, magnetic computer tapes.

3. Copies of this data on tape are available for cost, with the U. S. Coast Guard's concurrence. The data can be made compatible to be read by other systems. Also, hard copies of the data is readily available at minimal cost.

V. CONCLUSIONS

A. Capacity determination testing is a means for evaluating a manufacturer's quality control in production of his batteries.

B. The state-of-charge of a battery can be determined by knowing its voltage and charge current, and then applying this information to its proper performance characteristic curves.

C. Lead-acid type batteries:

1. A minimum of eighty percent of rated capacity can be expected to be obtained using low charge and discharge rates (Cm/100) at 20°C, regardless of how the manufacturer rates his batteries.

2. Expect a capacity loss of 35 to 70 percent at the -20°C temperature and an increase of 5 to 30 percent at the 50°C temperature.

3. Equilibrium battery voltages vary between the different types of batteries with those voltages at -20°C being from .7 to 1.2 volts higher than those at 50°C. Therefore, regulator temperature compensation coefficients should be based on observed equilibrium voltage temperature coefficients.

4. Water loss is significant at the C/67 to C/33 charge rates when the batteries are being overcharged and the loss at 50°C is slightly more than that at -20°C.

5. Although only the Willard type batteries could be compared, it is expected that only slight differences would occur in the performance characteristics between new and cycled (over 5-years life) batteries if the batteries were designed for operation in a photovoltaic power system similar to that proposed by the U. S. Coast Guard.

D. Nickel-cadimum pocket type batteries:

1. A Cm/100 charge rate is not efficient for these type batteries in that only 80 to 85 percent of rated capacity can be expected to be delivered at 20°C. An increase in the charge rate to a minimum of Cm/20 should result in 100 percent of rated capacity delivered. To incorporate a nickel-cadmium battery into a photovoltaic power system requires a basic change in the present design philosophy. In order to overcome the batteries low charge efficiency at low charge rates, the solar array current output

would have to be greatly increased relative to the battery capacity to increase the charge rate to a region where the nickel-cadmium battery efficiently accepts charge. A hypothetical power system with a nickel-cadmium battery would be configured with a 10 ampere-hour battery and a 50 to 100 watt solar array vice the present design of a 10 watt array with a 100 ampere-hour lead-calcium battery. This hypothetical system would not have the large capacity reserve of the present design and would also be more expensive. A large reduction in the price of solar arrays would improve the economics of a nickel-cadmium photovoltaic power system.

2. Expect minimum loss of capacity at -20°C and although the capacity test at 50°C also showed minimum loss at this temperature, it can be expected that a 50°C operating temperature will greatly reduce the life of these batteries whereas a 0°C to 10°C will result in maximum life.

3. Battery voltages, when fully charged, are approximately 2.5 volts higher at -20°C than at 50°C.

4. Weight loss is minimum at both the -20°C and 50°C test temperatures.

VI. RECOMMENDATIONS

A. Lead-acid type batteries should be deployed in photovoltaic power systems with emphasis placed on those batteries designed for this type of operation. Various types of lead-calcium grid batteries, which are readily available from a national retail outlet, are electrically compatible with a photovoltaic power system. However, further testing is necessary to evaluate their life expectancy.

B. Capacity determination tests should be performed on all batteries placed in service. These tests may be reduced to battery lot testing if a high confidence level is achieved.

C. Charge efficiency curves, for candidate batteries, should be generated using various low charge/discharge rates that the batteries would be subjected to in a photovoltaic power system.

D. Efforts should be continued to keep abreast of new advancements in battery technology in that continuing efforts are being pursued by the battery manufacturers to improve their products. One example is a new lead-acid battery (Cathanode) and is manufactured by GNB Batteries, a division of Gould, Inc. This battery is intended for automotive use, however, it may prove feasible for photovoltaic applications. It is advertised to deliver 40 percent more energy than other lead-acid batteries of comparable dimensions. The cost is approximately $90 and is available at national outlet stores.

APPENDIX A

TEST PLAN AND PROCEDURE
FOR BATTERY CHARACTERISTIC TESTS FOR SECONDARY BATTERIES

A. PURPOSE

1. The purpose of this document is to outline a test program to obtain the performance characteristics of secondary batteries. Evaluation of these characteristics by the U. S. Coast Guard will determine the suitability of various batteries to power the U. S. Coast Guard's lighted aids to navigation, utilizing a photovoltaic charging system.

B. OBJECTIVE

1. The objective is to develop a test plan, that when implemented, will provide the U. S. Coast Guard with performance characteristics of various types/models of batteries from different manufacturers. The test parameters will subject the batteries to conditions which may be experience if utilized in an aid to navigation, thereby allowing the U. S. Coast Guard to identify those batteries suitable for use with photovoltaic power systems.

C. TEST PLAN

1. The test plan, as outlined in enclosure (1), is designed to provide information pertaining to various performance characteristics of secondary batteries. The plan consists of three main parts and a description of each part is as follows:

(a) Baseline Capacity - determination of the batterie's actual capacity when subjected to three low rate (Cm/100) charges and discharges in which Cm = manufacturer's rated capacity, no matter how the battery is rated. Also, the manufacturer's quality control in producing these batteries will be indicated by the variation in capacity. The test temperature will be 20°C.

(b) Overcharge - determination of the batteries overcharge characteristics at six different charge rates ranging from Ca/33 to Ca/200 in which Ca = average actual capacity of the batteries. A Tafel Curve (voltage X time for each rate) can be generated for each battery which will indicate the equilibrium state of each type of battery at each rate. These characteristics will be evaluated at -20°C and 50°C.

(c) State-of-charge - determination of the state-of-charge characteristics at the 90 and 80 percent level for the same charge currents as in part 2. Various performance characteristic curves for each battery may be generated from this test. Evaluation will be at -20° and 50°C.

2. Water Loss:

(a) Determination of the water loss, during the various parts of the test plan, is desirable in that an evaluation of each batterie's loss will have to be assessed to determine its maintenance or replacement schedule if deployed in an aid to navigation system.

(b) Measurement of this loss is extremely difficult as the weight of a battery may be 30 kilograms and the loss will need to be measured in tenths of a gram. Investigation has found that only one manufacturer, Toledo Scales, can provide an instrument that will measure this loss with the accuracy required.

(c) Specific intervals are indicated in the test plan to measure the water loss and from this data various voltage, current versus water loss characteristic curves may be generated.

3. Test Samples:

(a) Sample Size - A minimum of three batteries of each type/model, as recommended by the U. S. Coast Guard, would be required. The batteries would be tested in series and not in any series/parallel configuration.

(b) Mr. Ralph Chipman, statistician at Crane, stated that three batteries would be sufficient for a sample size depending on the variability of each manufacturer's batteries.

(c) Evaluation of batteries with an equivalent of 4-5 years of service with photovoltaic systems on aids to navigation compared with new batteries of the same type/model would be ideal for comparison of changing characteristics. An accelerated test program to generate "old" batteries is not available and would require a comprehensive study and life-test program for validation. Batteries with this type life may be available from the U. S. Coast Guard through their Research and Development Center at Croton, Connecticut.

(d) It is estimated that the total time required to complete these tests for each manufacturer is 1915 hours.

D. DATA ANALYSIS

1. Generation of curves depicting the performance characteristics of each type/model battery, under various test conditions, would be submitted to the U. S. Coast Guard for their evaluation.

TEST PLAN PROCEDURE
for
Battery Characteristic Tests

I. Inspection

A. Each battery will be visually inspected for any abnormalities or manufacturing defects.

II. Filling (when applicable)

A. Each battery will be filled with electrolyte to the proper level according to the manufacturer's specifications.

III. Weight

A. Each battery will be weighed prior to and following baseline capacity determination tests.

B. Each battery will be weighed at specific intervals during the overcharge and state-of-charge evaluation tests.

IV. Baseline Capacity Determination Tests (20°C)

A. Allow batteries to obtain temperature equilibrium at 20°C with a minimum stand time of 24 hours.

B. Charge at Cm/100 until the batteries obtain a 100 percent state-of-charge (SOC) according to the manufacturer's specifications, where Cm is the manufacturer's rated capacity of the battery.

C. Discharge each battery at Cm/100 to 0 percent SOC as determined by the cut-off voltage for each type battery.

D. Repeat B and C twice. Determine average actual capacity of batteries, based on the mean, from the last discharge. An additional charge and discharge cycle may be performed if variation in capacities of the batteries is significant.

NOTE: The value C referred to in the overcharge and state-of-charge evaluation tests will be the actual mean value of the battery as previously determined. (Ca)

V. Overcharge Evaluation Test at -20°C

A. Allow batteries to obtain temperature equilibrium at -20°C with a minimum stand time of 24 hours.

B. Charge at C/100 until the batteries reach 95 percent SOC.

C. Change charge rate to C/33 and continue charge until each battery reaches voltage equilibrium.*

D. Repeat C with charge rates of C/40, C/50, C/67, C/100, and C/200.

NOTE: Battery weights will be recorded at the start and end in Part B and then on an hourly basis for parts C and D.

VI. State-of-Charge Evaluation Test at -20°C

A. Evaluation at the 90 percent SOC level will consist of six discharges at the C/100 rate for 10 hours (10 percent depth-of-discharge); followed by a charge as noted. There will be a stand period of 12 hours between each charge and discharge. The procedure is as follows:

	Condition	Rate	Time (hrs)		Condition	Rate	Time (hrs)
1.	Discharge	C/100	10	4.	Discharge	C/100	10
	Charge	C/33	3.3		Charge	C/67	6.7
	Stand		12		Stand		12
2.	Discharge	C/100	10	5.	Discharge	C/100	10
	Charge	C/40	4		Charge	C/100	10
	Stand		12		Stand		12
3.	Discharge	C/100	10	6.	Discharge	C/100	10
	Charge	C/50	5		Charge	C/200	20
	Stand		12		Stand		12

B. Evaluation at the 80 percent SOC level is the same as part A except for the times of discharge and charge. The procedure is as follows:

	Condition	Rate	Time (hrs)		Condition	Rate	Time (hrs)
1.	Discharge	C/100	20	4.	Discharge	C/100	20
	Charge	C/33	6.6		Charge	C/67	13.4
	Stand		12		Stand		12
2.	Discharge	C/100	20	5.	Discharge	C/100	20
	Charge	C/40	8		Charge	C/100	20
	Stand		12		Stand		12
3.	Discharge	C/100	20	6.	Discharge	C/100	20
	Charge	C/50	10		Charge	C/200	40
	Stand		12		Stand		12

NOTE: Battery weights will be recorded during charge in parts A and B as follows: Conditions 1, 2, 3, and 4 - hourly; Conditions 5 and 6 - every 2 hours. Weight will also be recorded at the end of each discharge and stand period.

*Equilibrium voltage varies with type of battery

VII. Overcharge Evaluation at 50°C

A. Same procedure as V except at the temperature of 50°C.

VIII. State-of-Charge Evaluation Test at 50°C

A. Same procedure at VI except at the test temperature of 50°C.

NOTE: The U. S. Coast Guard made the following changes in the test plan following test completion of the first two test samples, which were the new and cycled Willard batteries:

(1) Equilibrium changes to follow each discharge during the state-of-charge tests.

(2) Capacity discharges to follow completion of the state-of-charge tests at each temperature.

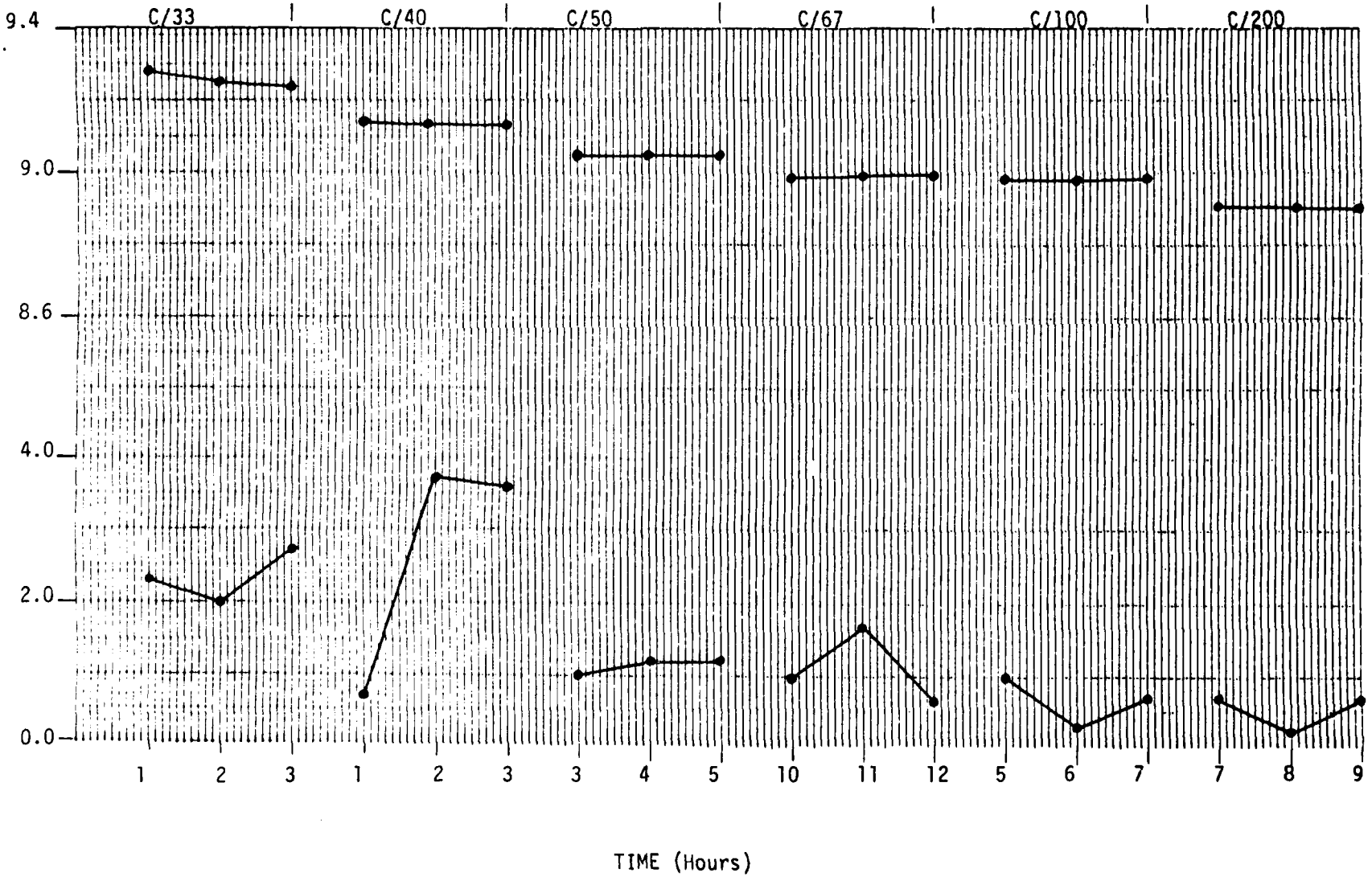
(3) Frequency of weight data readings to be reduced during state-of-charge tests in which they will only be taken at end of discharge and stand, and at 100 percent per charge returned plus end-of-charge (equilibrium).

(4) Complete Tafel curves need not be generated; but only equilibrium voltage versus time (last three stabilized data points).

APPENDIX B

OVERCHARGE EVALUATION GRAPHS

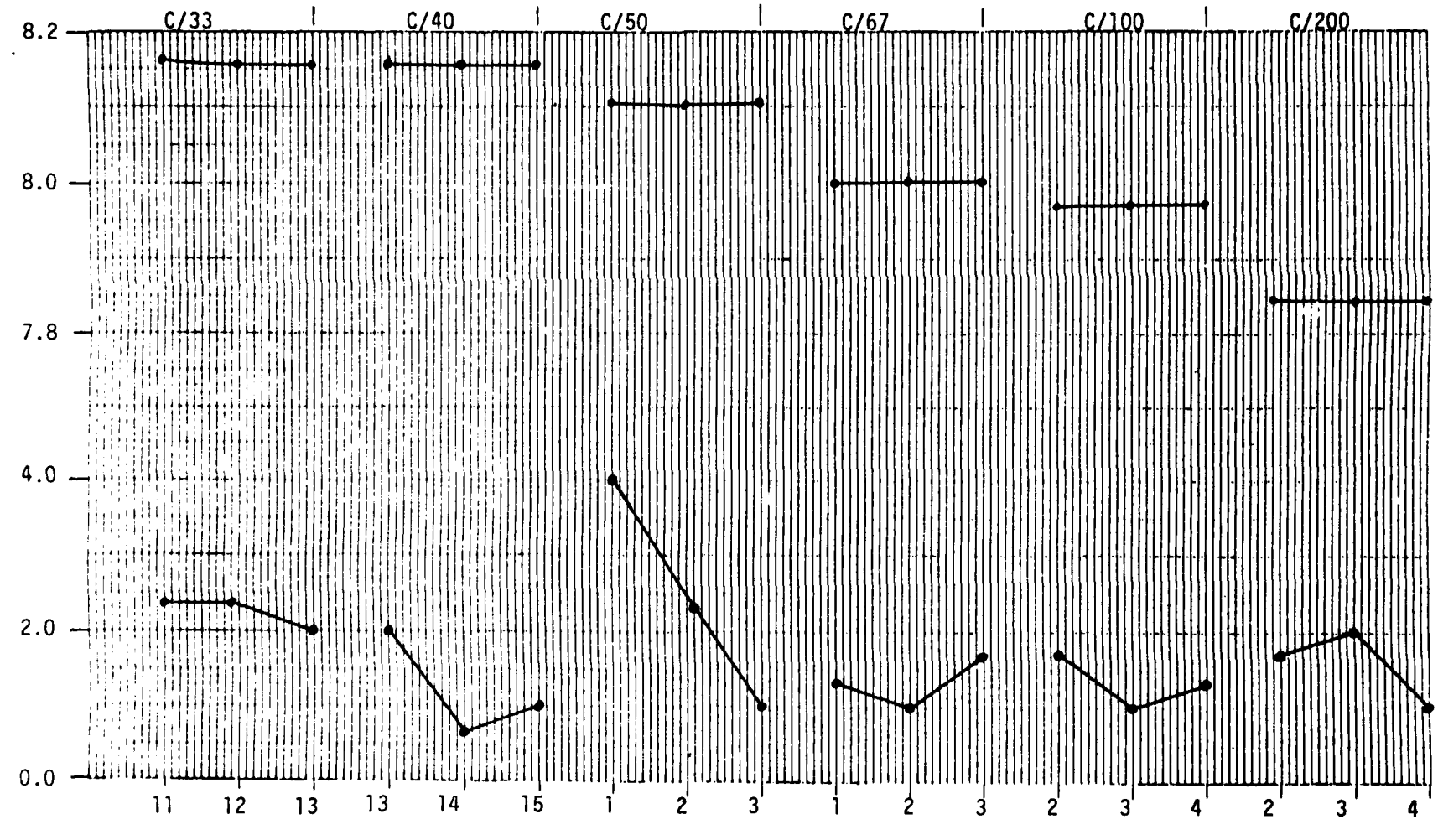
OVERCHARGE EVALUATION TEST AT -20 C
EQUILIBRIUM VOLTAGE AND WT. LOSS VS. CHARGE RATE
WILLARD, MODEL UD-3-3, P/N 8241
(C =82 Ampere-Hours)



B-2

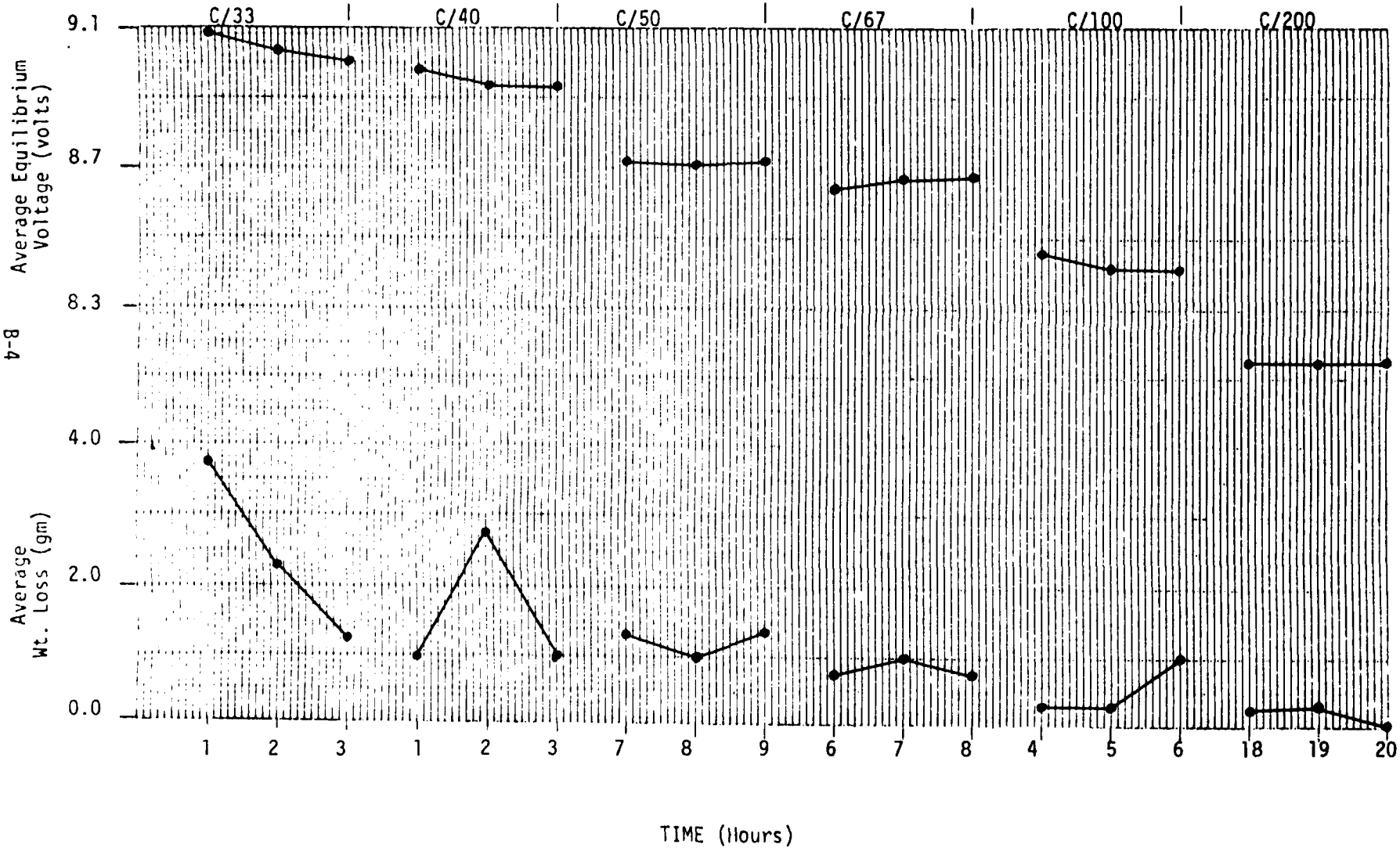
MOEC/C 83-75

OVERCHARGE EVALUATION TEST AT 50°C
EQUILIBRIUM VOLTAGE AND WT. LOSS VS. CHARGE RATE
WILLARD, MODEL DD-3-3, P/N 8241
(C = 82 Ampere-Hours)



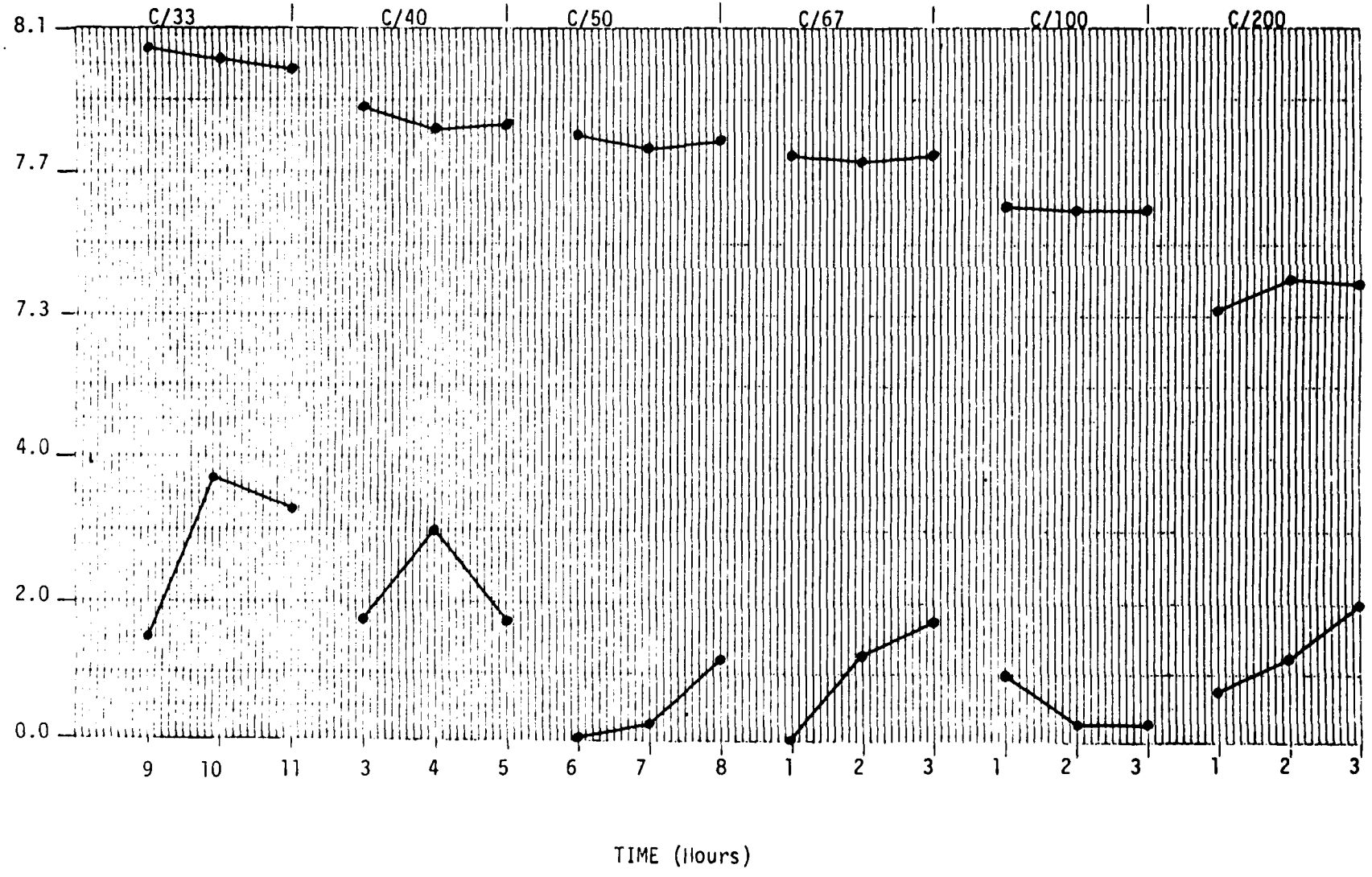
WOECO 83-75

OVERCHARGE EVALUATION TEST AT -20°C
EQUILIBRIUM VOLTAGE AND WT. LOSS VS. CHARGE RATE
WILLARD, MODEL DD-[illegible]3, P/N 8241 (Cycled)
(C = 85 Ampere-Hours)



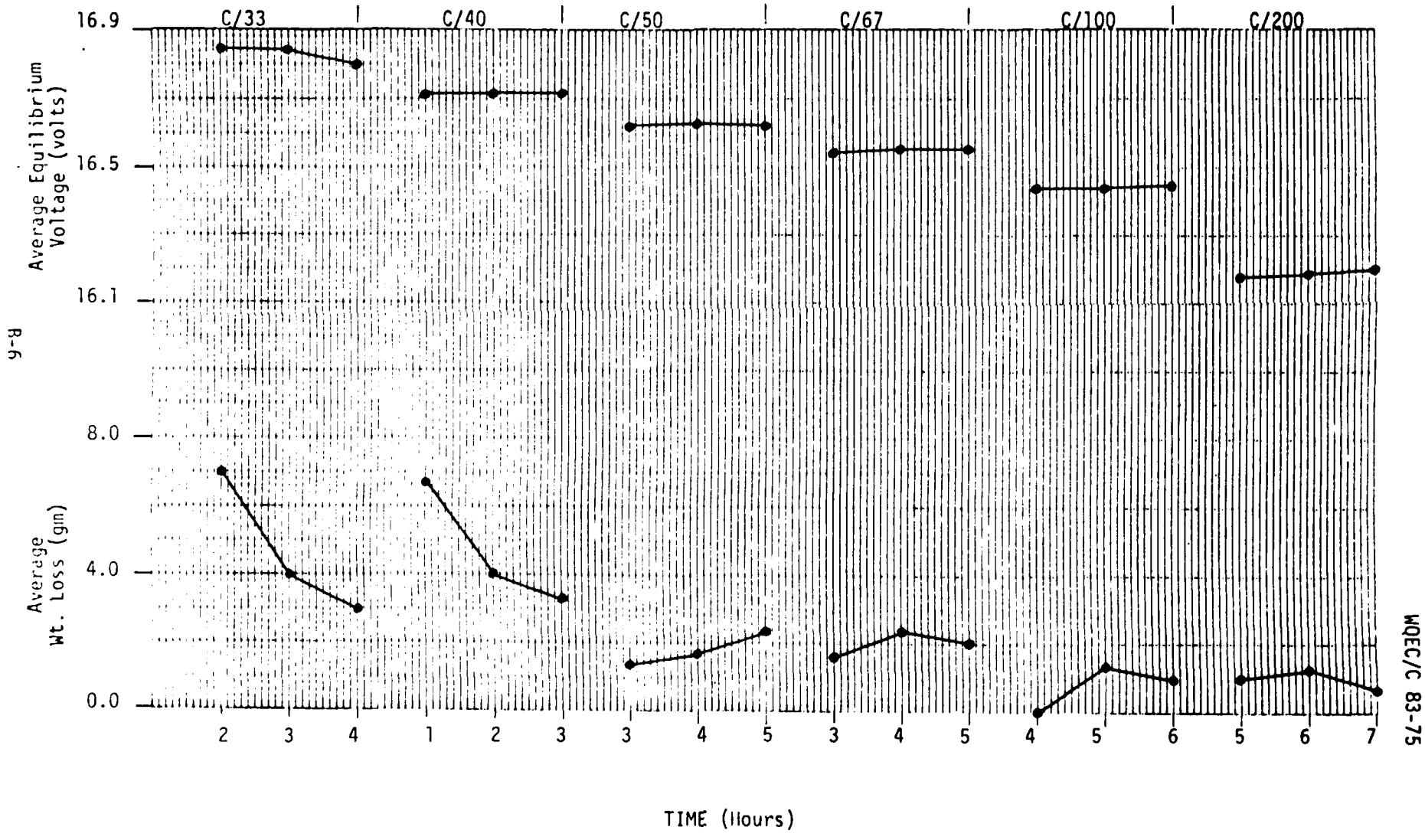
MOEC/C 83-75

OVERCHARGE EVALUATION TEST AT 50°C
EQUILIBRIUM VOLTAGE AND WT. LOSS VS. CHARGE RATE
WILLARD, MODEL DD-3-3, P/N 8241 (Cycled)
(C = 85 Ampere-Hours)



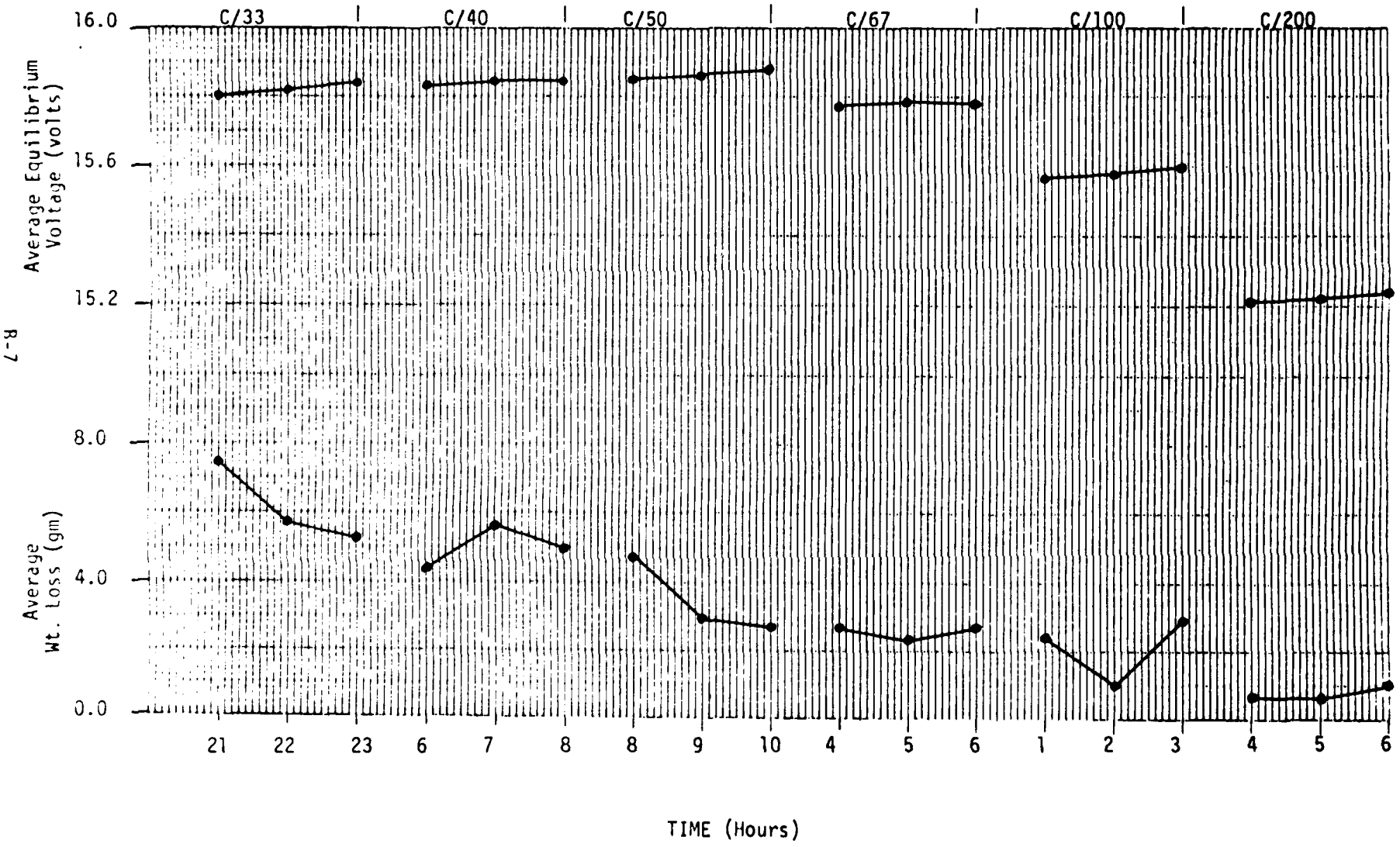
MDEC/C 83-75

OVERCHARGE EVALUATION TEST AT -20°C
EQUILIBRIUM VOLTAGE AND WT. LOSS VS. CHARGE RATE
DELCO-REMY 2000
(C =93 Ampere-Hours)



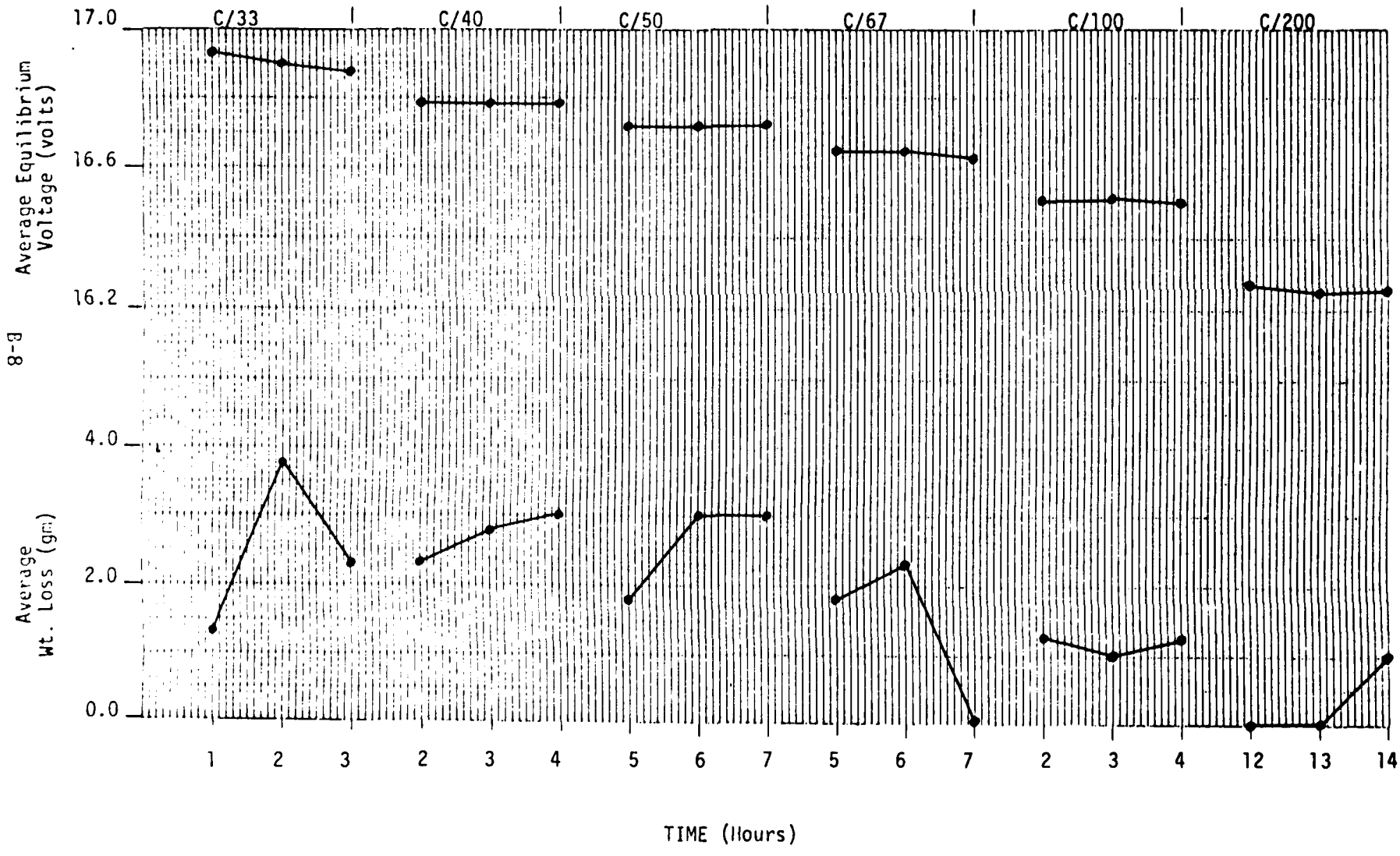
WQEC/C 83-75

OVERCHARGE EVALUATION TEST AT 50°C
EQUILIBRIUM VOLTAGE AND WT. LOSS VS. CHARGE RATE
DELCO-REMY 2000
(C =93 Ampere-Hours)

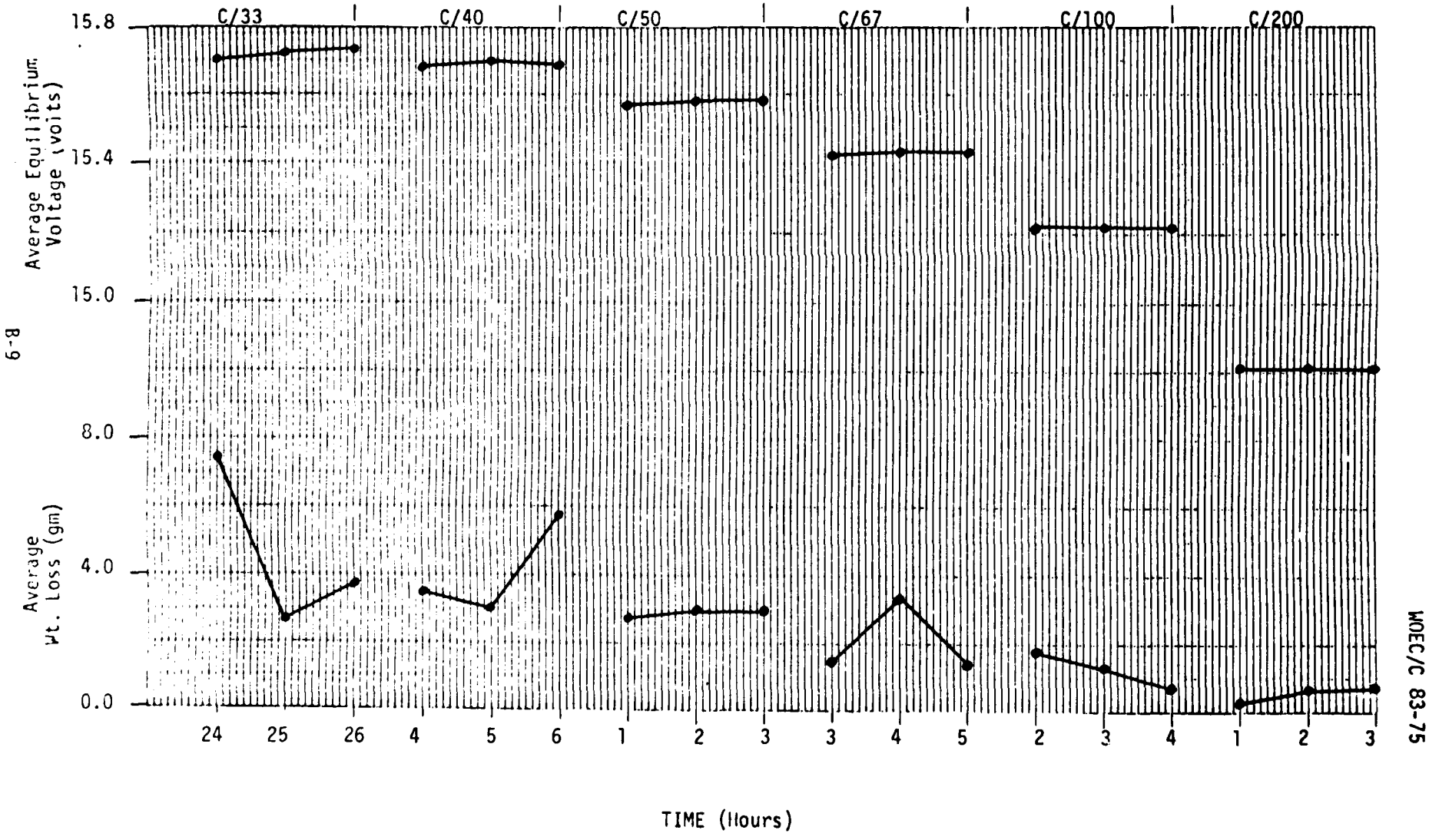


OVERCHARGE EVALUATION TEST AT -20°C
EQUILIBRIUM VOLTAGE AND WT. LOSS VS. CHARGE RATE

1/2 C. PENNEY SURVIVOR 72
(C = 70 Ampere-Hours)



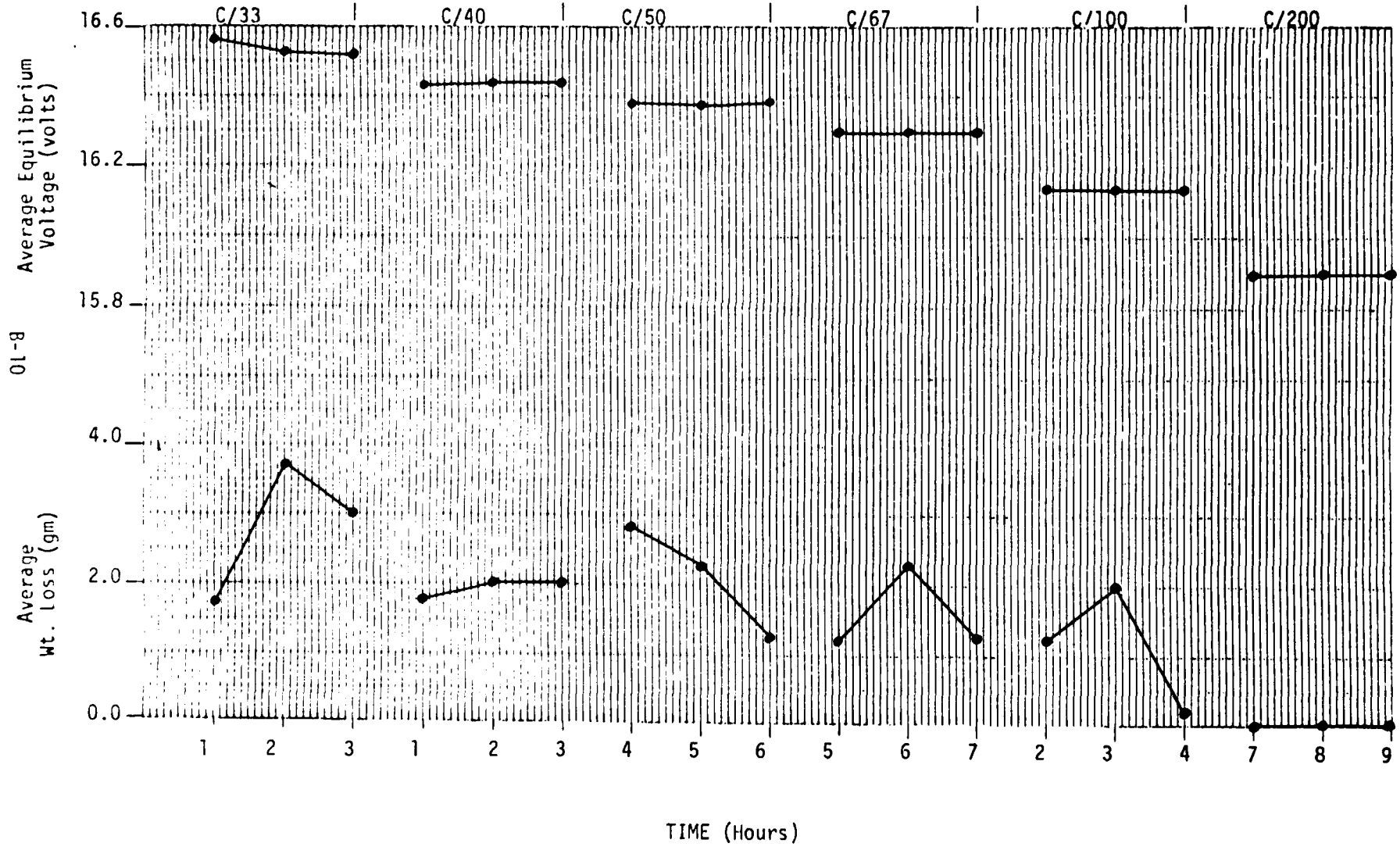
OVERCHARGE EVALUATION TEST AT 50°C
EQUILIBRIUM VOLTAGE AND WT. LOSS VS. CHARGE RATE
J. C. PENNEY SURVIVOR 72
(C = 70Ampere-Hours)



6-8

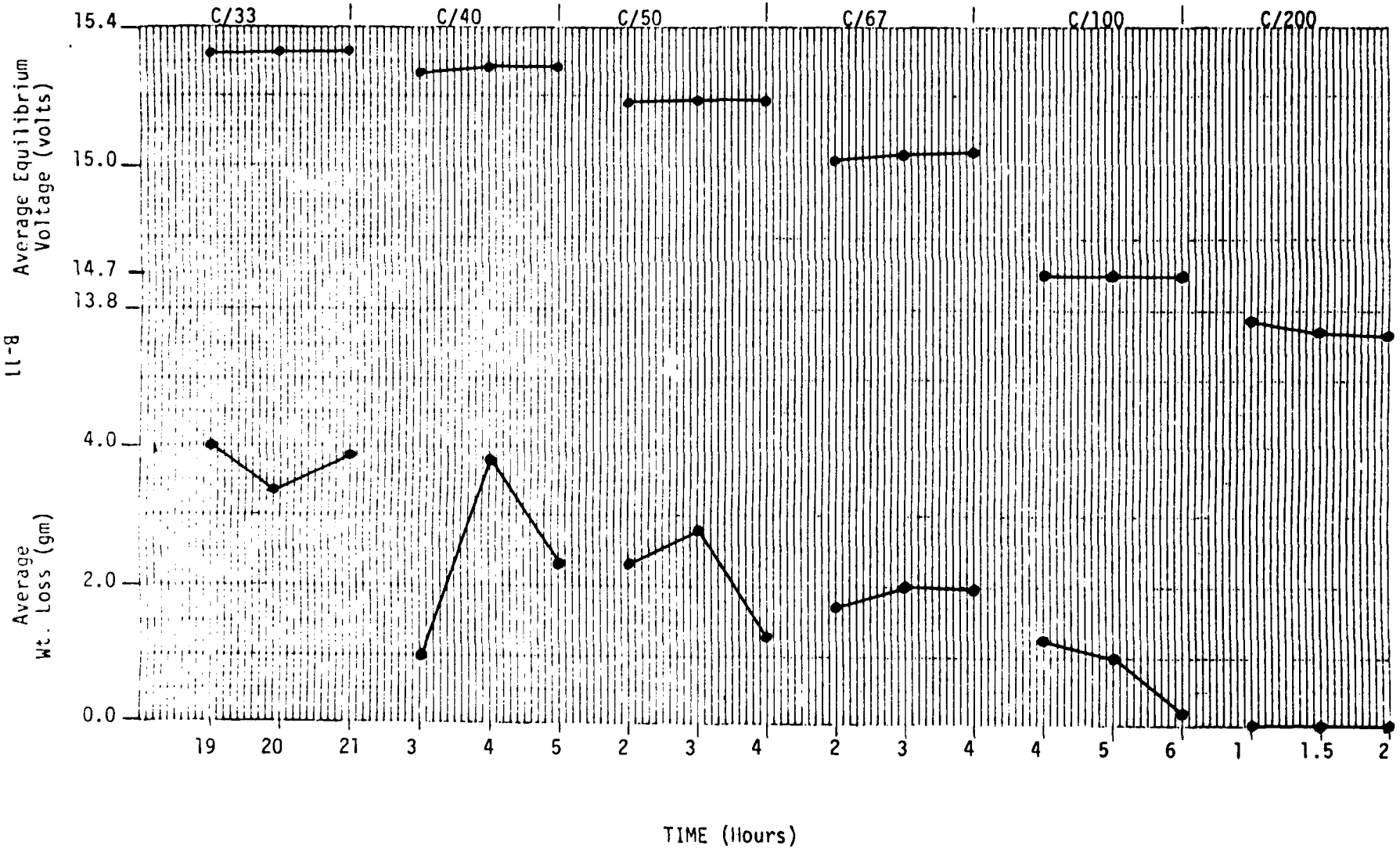
MOEC/C 83-75

OVERCHARGE EVALUATION TEST AT -20°C
EQUILIBRIUM VOLTAGE AND WT. LOSS VS. CHARGE RATE
GLOBE UNION GC 12550
(C =58 Ampere-Hours)



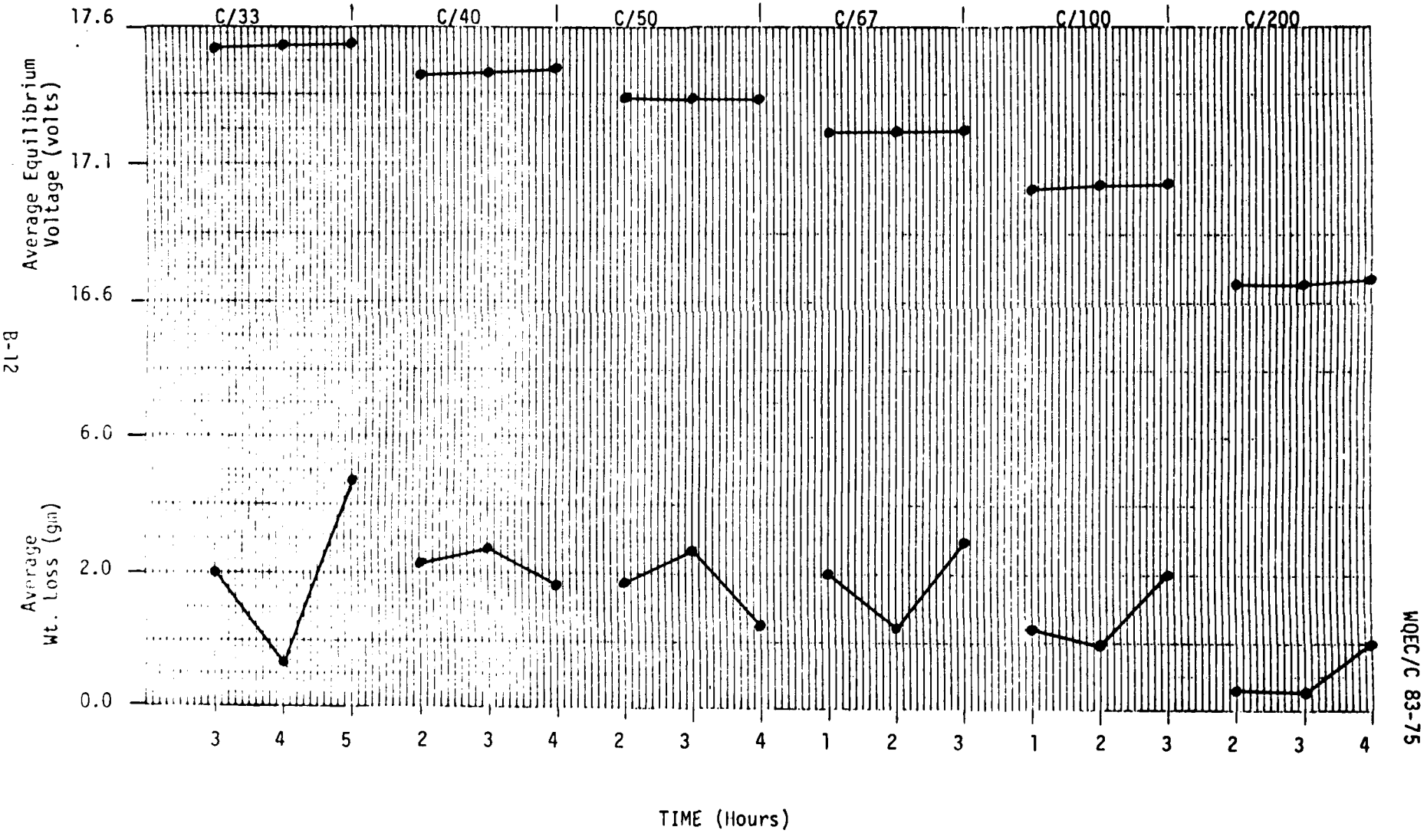
MDEC/C 83-75

OVERCHARGE EVALUATION TEST AT 50°C
EQUILIBRIUM VOLTAGE AND WT. LOSS VS. CHARGE RATE
GLOBE UNION GC 12550
(C =58 Ampere-Hours)

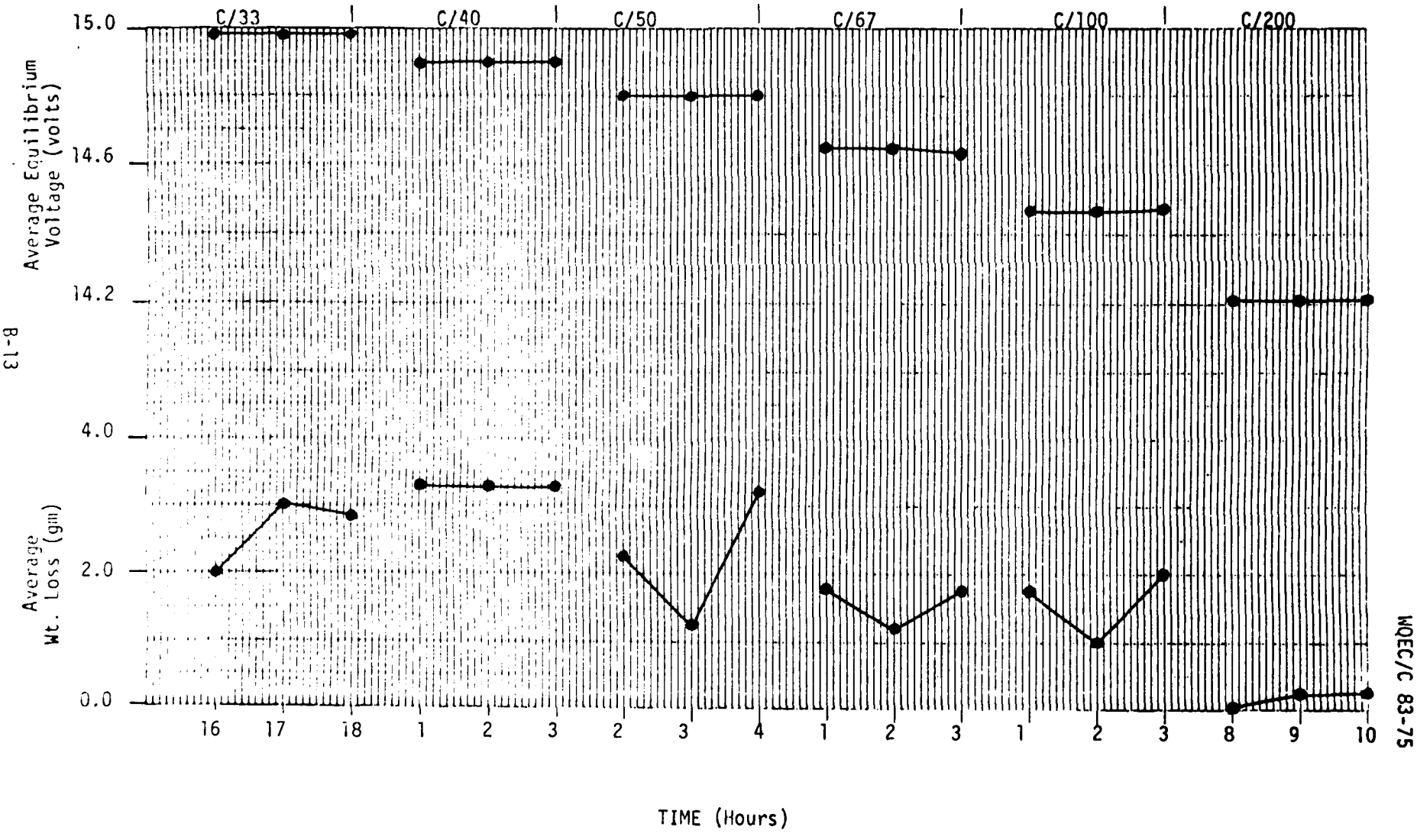


MOEC/C 83-75.

OVERCHARGE EVALUATION TEST AT -20°C
EQUILIBRIUM VOLTAGE AND WT. LOSS VS. CHARGE RATE
NIFE - NICKEL CADMIUM - L-302-2
(C = 55Ampere-Hours)



OVERCHARGE EVALUATION TEST AT 50 C
EQUILIBRIUM VOLTAGE AND WT. LOSS VS. CHARGE RATE
NIFE - NICKEL- CADMIUM - L-302-2
(C =55 Ampere-Hours)



WQEC/C 83-75

APPENDIX C

OVERCHARGE EVALUATION TEST DATA

OVERCHARGE EVALUATION TEST DATA AT -20°
WILLARD, MODEL DD-3-3, P/N 8241
(C = 82 Ampere-Hours)

RATE	Battery # 1			Battery # 2			Battery # 3			Average	
	Time (Hrs)	Voltage	Wt Loss (gm/hr)	Time (Hrs)	Voltage	Wt Loss (gm/hr)	Time (Hrs)	Voltage	Wt Loss (gm/hr)	Voltage	Wt Loss (gm/hr)
C/33	1	9.26	2.0	1	9.24	2.0	1	9.35	3.0	9.28	2.3
	2	9.24	1.0	2	9.22	1.0	2	9.28	4.0	9.25	2.0
	3	9.22	2.0	3	9.21	0.0	3	9.26	6.0	9.23	2.7
C/40	1	9.15	0.0	1	9.13	1.0	1	9.17	0.0	9.15	0.7
	2	9.14	5.0	2	9.12	4.0	2	9.16	2.0	9.14	3.7
	3	9.13	3.0	3	9.11	3.0	3	9.15	4.0	9.13	3.3
C/50	3	9.06	1.0	3	9.04	1.0	2	9.06	1.0	9.05	1.0
	4	9.06	2.0	4	9.04	1.0	3	9.06	1.0	9.05	1.3
	5	9.06	1.0	5	9.04	1.0	4	9.06	2.0	9.05	1.3
C/67	10	9.00	1.0	10	8.98	1.0	8	8.93	1.0	8.97	1.0
	11	9.00	1.0	11	8.98	2.0	9	8.94	2.0	8.97	1.7
	12	9.00	1.0	12	8.98	0.0	10	8.94	1.0	8.97	0.7
C/100	5	8.91	1.0	4	8.88	1.0	5	8.89	1.0	8.90	1.0
	6	8.91	0.0	5	8.88	1.0	6	8.89	0.0	8.89	0.3
	7	8.91	1.0	6	8.88	0.0	7	8.89	1.0	8.89	0.7
C/200	7	8.76	1.0	6	8.88	0.0	8	8.89	1.0	8.84	0.7
	8	8.76	0.0	7	8.88	1.0	9	8.89	0.0	8.84	0.3
	9	8.76	1.0	8	8.88	0.0	10	8.89	1.0	8.84	0.7

OVERCHARGE EVALUATION TEST DATA AT 50°C
WILLARD, MODEL DD-3-3, P/N 8241
(C = 82 Ampere-Hours)

RATE	Battery # 1			Battery # 2			Battery # 3			Average	
	Time (Hrs)	Voltage	Wt Loss (gm/hr)	Time (Hrs)	Voltage	Wt Loss (gm/hr)	Time (Hrs)	Voltage	Wt Loss (gm/hr)	Voltage	Wt Loss (gm/hr)
C/33	11	8.12	5.0	12	8.23	2.0	11	8.15	1.0	8.17	2.7
	12	8.12	0.0	13	8.22	6.0	12	8.15	2.0	8.16	2.7
	13	8.12	4.0	14	8.21	1.0	13	8.15	1.0	8.16	2.0
C/40	13	8.13	0.0	14	8.23	0.0	13	8.14	6.0	8.16	2.0
	14	8.13	0.0	15	8.22	2.0	14	8.14	0.0	8.16	0.7
	15	8.13	2.0	16	8.22	1.0	15	8.14	0.0	8.16	1.0
C/50	1	8.08	4.0	1	8.16	7.0	1	8.08	1.0	8.11	4.0
	2	8.08	2.0	2	8.15	1.0	2	8.08	2.0	8.10	2.3
	3	8.08	1.0	3	8.15	1.0	3	8.09	1.0	8.11	1.0
C/67	1	8.00	1.0	1	8.05	2.0	1	8.00	1.0	8.02	1.3
	2	8.01	1.0	2	8.06	1.0	2	8.01	1.0	8.03	1.0
	3	8.01	3.0	3	8.06	1.0	3	8.01	2.0	8.03	1.7
C/100	2	7.91	2.0	2	7.95	2.0	1	7.90	1.0	7.93	1.7
	3	7.91	1.0	3	7.95	0.0	2	7.90	2.0	7.93	1.0
	4	7.91	3.0	4	7.95	0.0	3	7.90	1.0	7.93	1.3
C/200	2	7.74	2.0	1	7.76	2.0	1	7.72	1.0	7.74	1.7
	3	7.74	1.0	2	7.76	3.0	2	7.72	2.0	7.74	2.0
	4	7.74	1.0	3	7.76	2.0	3	7.72	0.0	7.74	1.0

OVERCHARGE EVALUATION TEST DATA AT -20°C
WILLARD, MODEL DD-3-3, P/B 8241 (Cycled)
(C = 85 Ampere-Hours)

RATE	Battery # 1 Time (Hrs)	Battery # 1 Voltage	Battery # 1 Wt Loss (gm/hr)	Battery # 2 Time (Hrs)	Battery # 2 Voltage	Battery # 2 Wt Loss (gm/hr)	Battery # 3 Time (Hrs)	Battery # 3 Voltage	Battery # 3 Wt Loss (gm/hr)	Average Voltage	Average Wt Loss (gm/hr)
C/33	1.0	9.105	4.0	1.0	9.169	2.0	1.0	8.98	5.0	9.09	3.7
	2.0	9.088	2.0	2.0	9.153	3.0	2.0	8.88	2.0	9.04	2.3
	3.0	9.078	2.0	3.0	9.142	2.0	3.0	8.80	0.0	9.01	1.3
C/40	1.0	9.00	2.0	2.0	9.08	2.0	1.0	8.57	0.0	8.88	1.0
	2.0	8.98	2.0	3.0	9.06	1.0	2.0	8.48	6.0	8.84	2.7
	3.0	8.98	2.0	4.0	9.05	0.0	3.0	8.46	1.0	8.83	1.0
C/50	7.0	8.89	1.0	4.0	9.00	2.0	4.0	8.26	1.0	8.72	1.3
	8.0	8.89	2.0	5.0	9.00	1.0	5.0	8.24	0.0	8.71	1.0
	9.0	8.90	2.0	6.0	9.00	1.0	6.0	8.25	1.0	8.72	1.3
C/67	6.0	8.85	1.0	9.0	8.94	1.0	9.0	8.14	0.0	8.64	.7
	7.0	8.85	1.0	10.0	8.94	1.0	10.0	8.22	1.0	8.67	1.0
	8.0	8.85	1.0	11.0	8.94	1.0	11.0	8.25	0.0	8.68	.7
C/100	4.0	8.72	1.0	5.0	8.86	0.0	2.0	7.84	0.0	8.47	.3
	5.0	8.52	0.0	6.0	8.86	1.0	3.0	7.84	0.0	8.41	.3
	6.0	8.53	1.0	7.0	8.87	1.0	4.0	7.84	1.0	8.41	1.0
C/200	18.0	8.44	1.0	5.0	8.71	0.0	2.0	7.60	0.0	8.25	.3
	19.0	8.43	1.0	6.0	8.71	0.0	3.0	7.58	0.0	8.24	.3
	20.0	8.42	0.0	7.0	8.72	0.0	4.0	7.58	0.0	8.24	0.0

OVERCHARGE EVALUATION TEST DATA AT 50°C
WILLARD, MODEL UD-3-3, P/N 8241 (Cycled)
(C = 85 Ampere-Hours)

RATE	Battery # 1			Battery # 2			Battery # 3			Average	
	Time (Hrs)	Voltage	Wt Loss (gm/hr)	Time (Hrs)	Voltage	Wt Loss (gm/hr)	Time (Hrs)	Voltage	Wt Loss (gm/hr)	Voltage	Wt Loss (gm/hr)
C/33	9.0	8.0	1.0	9.0	8.15	3.0	8.0	7.88	1.0	8.04	1.7
	10.0	8.08	5.0	10.0	8.15	4.0	9.0	7.81	2.0	8.01	3.7
	11.0	8.05	3.0	11.0	8.15	4.0	10.0	7.74	3.0	7.98	3.3
C/40	3.0	7.82	2.0	2.0	8.11	3.0	3.0	7.71	0.0	7.88	1.7
	4.0	7.71	3.0	3.0	8.11	4.0	4.0	7.65	2.0	7.82	3.0
	5.0	7.77	1.0	4.0	8.11	2.0	5.0	7.60	2.0	7.83	1.7
C/50	6.0	7.73	0.0	7.0	8.11	0.0	7.0	7.57	0.0	7.80	0.0
	7.0	7.73	0.0	8.0	8.11	0.0	8.0	7.36	1.0	7.73	0.3
	8.0	7.73	4.0	9.0	8.11	0.0	9.0	7.51	0.0	7.78	1.3
C/67	1.0	7.67	0.0	1.0	8.04	0.0	1.0	7.57	0.0	7.76	0.0
	2.0	7.67	2.0	2.0	8.05	0.0	2.0	7.50	1.0	7.74	1.3
	3.0	7.67	1.0	3.0	8.05	2.0	3.0	7.52	2.0	7.75	1.7
C/100	1.0	7.58	2.0	1.0	7.96	1.0	1.0	7.28	1.0	7.61	1.0
	2.0	7.58	0.0	2.0	7.95	1.0	2.0	7.23	0.0	7.59	.3
	3.0	7.59	0.0	3.0	7.95	1.0	3.0	7.26	0.0	7.60	.3
C/200	1.0	7.44	1.0	1.0	7.74	3.0	1.0	7.05	0.0	7.31	.7
	2.0	7.44	2.0	2.0	7.74	1.0	2.0	7.08	0.0	7.42	1.3
	3.0	7.44	0.0	3.0	7.74	0.0	3,0	7.02	0.0	7.40	2.0

OVERCHARGE EVALUATION TEST DATA AT -20°C
DELCO-REMY 2000
(C = 93 Ampere-Hours)

RATE	Battery # 1			Battery # 2			Battery # 3			Average	
	Time (Hrs)	Voltage	Wt Loss (gm/hr)	Time (Hrs)	Voltage	Wt Loss (gm/hr)	Time (Hrs)	Voltage	Wt Loss (gm/hr)	Voltage	Wt Loss (gm/hr)
C/33	2	16.81	4.0	2	16.89	10.0	2	16.84	7.0	16.85	7.0
	3	16.79	3.0	3	16.87	7.0	3	16.82	2.0	16.83	4.0
	4	16.75	1.0	4	16.85	3.0	4	16.80	5.0	16.80	3.0
C/40	1	16.68	6.0	1	16.76	8.0	1	16.71	6.0	16.71	6.7
	2	16.68	4.0	2	16.76	4.0	2	16.70	4.0	16.71	4.0
	3	16.68	6.0	3	16.75	1.0	3	16.70	3.0	16.71	3.3
C/50	3	16.60	2.0	3	16.67	2.0	3	16.63	0.0	16.63	1.3
	4	16.60	2.0	4	16.67	0.0	4	16.63	3.0	16.63	1.7
	5	16.61	4.0	5	16.67	2.0	5	16.63	1.0	16.63	2.3
C/67	3	16.52	2.0	3	16.58	0.0	3	16.55	3.0	16.55	1.7
	4	16.53	4.0	4	16.59	1.0	4	16.55	2.0	16.56	2.3
	5	16.53	3.0	5	16.59	2.0	5	16.56	1.0	16.56	2.0
C/100	4	16.42	0.0	4	16.47	0.0	4	16.44	0.0	16.44	0.0
	5	16.42	1.0	5	16.48	1.0	5	16.45	2.0	16.45	1.3
	6	16.43	3.0	6	16.48	0.0	6	16.46	0.0	16.46	1.0
C/200	5	16.15	0.0	6	16.20	2.0	7	16.20	1.0	16.18	1.0
	6	16.16	1.0	7	16.21	2.0	8	16.21	1.0	16.19	1.3
	7	16.16	0.0	8	16.22	2.0	9	16.21	0.0	16.20	0.7

OVERCHARGE EVALUATION TEST DATA AT 50°C
DELCO-REMY 2000
(C = 93 Ampere-Hours)

RATE	Battery # 1			Battery # 2			Battery # 3			Average	
	Time (Hrs)	Voltage	Wt Loss (gm/hr)	Time (Hrs)	Voltage	Wt Loss (gm/hr)	Time (Hrs)	Voltage	Wt Loss (gm/hr)	Voltage	Wt Loss (gm/hr)
C/33	21	15.76	6.0	21	15.82	8.0	21	15.81	8.0	15.80	7.3
	22	15.78	6.0	22	15.85	6.0	22	15.83	5.0	15.82	5.7
	23	15.81	7.0	23	15.86	5.0	23	15.84	4.0	15.84	5.3
C/40	6	15.81	5.0	5	15.86	3.0	4	15.82	5.0	15.83	4.3
	7	15.82	5.0	6	15.86	7.0	5	15.83	5.0	15.84	5.7
	8	15.83	6.0	7	15.87	5.0	6	15.84	4.0	15.85	5.0
C/50	8	15.85	2.0	6	15.87	8.0	8	15.87	4.0	15.86	4.7
	9	15.86	4.0	7	15.88	2.0	9	15.88	3.0	15.87	3.0
	10	15.86	3.0	8	15.89	2.0	10	15.89	3.0	15.88	2.7
C/67	4	15.76	2.0	4	15.81	3.0	3	15.77	3.0	15.78	2.7
	5	15.77	3.0	5	15.81	2.0	4	15.78	2.0	15.79	2.3
	6	15.77	3.0	6	15.82	3.0	5	15.79	2.0	15.79	2.7
C/100	1	15.55	1.0	1	15.59	4.0	1	15.57	2.0	15.57	2.3
	2	15.57	0.0	2	15.61	1.0	2	15.59	2.0	15.59	1.0
	3	15.58	3.0	3	15.62	4.0	3	15.60	2.0	15.60	3.0
C/200	4	15.20	0.0	4	15.22	0.0	4	15.21	2.0	15.21	0.7
	5	15.20	2.0	5	15.24	0.0	5	15.22	0.0	15.22	0.7
	6	15.21	1.0	6	15.25	1.0	6	15.23	1.0	15.23	1.0

OVERCHARGE EVALU ON TEST DATA AT -20°C
J. C. PENNEY SURVIVOR 72
(C = 70 Ampere-Hours)

RATE	Battery # 1 Time (Hrs)	Voltage	Wt Loss (gm/hr)	Battery # 2 Time (Hrs)	Voltage	Wt Loss (gm/hr)	Battery # 3 Time (Hrs)	Voltage	Wt Loss (gm/hr)	Average Voltage	Average Wt Loss (gm/hr)
	1	16.85	1.0	1	16.87	1.0	1	17.10	2.0	16.94	1.3
C/33	2	16.80	3.0	2	16.83	4.0	2	17.07	4.0	16.90	3.7
	3	16.78	2.0	3	16.80	3.0	3	17.04	2.0	16.87	2.3
	2	16.69	2.0	2	16.72	3.0	2	16.93	2.0	16.78	2.3
C/40	3	16.70	2.0	3	16.72	3.0	3	16.93	3.0	16.78	2.7
	4	16.70	3.0	4	16.72	3.0	4	16.92	3.0	16.78	3.0
	5	16.65	2.0	5	16.68	2.0	6	16.87	1.0	16.73	1.7
C/50	6	16.65	2.0	6	16.68	2.0	7	16.87	5.0	16.73	3.0
	7	16.65	4.0	7	16.68	3.0	8	16.87	2.0	16.73	3.0
	5	16.58	2.0	5	16.62	2.0	5	16.79	1.0	16.66	1.7
C/67	6	16.58	2.0	6	16.62	3.0	6	16.79	2.0	16.66	2.3
	7	16.58	0.0	7	16.62	0.0	7	16.79	0.0	16.63	0.0
	2	16.43	3.0	2	16.46	0.0	2	16.63	1.0	16.51	1.3
C/100	3	16.43	1.0	3	16.46	0.0	3	16.63	2.0	16.51	1.0
	4	16.42	0.0	4	16.46	0.0	4	16.63	4.0	16.50	1.3
	12	16.20	0.0	12	16.24	0.0	12	16.40	0.0	16.28	0.0
C/200	13	16.18	0.0	13	16.22	0.0	13	16.38	0.0	16.26	0.0
	14	16.18	1.0	14	16.22	1.0	14	16.38	1.0	16.26	1.0
	1	16.50	0.0	1	16.54	1.0	1	16.72	1.0	16.58	0.7
C/100	2	16.49	3.0	2	16.52	1.0	2	16.71	1.0	16.58	1.7
	3	16.49	1.0	3	16.52	3.0	3	16.70	2.0	16.57	2.0
	2	16.64	0.0	1	16.67	0.0	1	16.86	2.0	16.72	0.7
C/67	3	16.62	3.0	2	16.66	4.0	2	16.84	2.0	16.71	3.0
	4	16.62	1.0	3	16.66	2.0	3	16.83	3.0	16.70	2.0
	1	16.72	5.0	1	16.75	3.0	1	16.94	2.0	16.80	3.3
C/50	2	16.71	2.0	2	16.74	5.0	2	16.93	5.0	16.79	4.0
	3	16.70	2.0	3	16.74	0.0	3	16.92	0.0	16.79	0.7
	1	16.76	5.0	1	16.80	4.0	1	16.99	6.0	16.85	5.0
C/40	2	16.75	1.0	2	16.79	3.0	2	16.99	2.0	16.85	2.0
	3	16.75	1.0	3	16.79	2.0	3	16.99	2.0	16.84	1.7
	1	16.84	5.0	1	16.88	5.0	1	17.07	6.0	16.93	5.3
C/33	2	16.82	3.0	2	16.85	2.0	2	17.05	4.0	16.91	3.0
	3	16.80	8.0	3	16.84	11.0	3	17.04	6.0	16.89	8.3

OVERCHARGE EVALUATION TEST DATA AT 50°C
J. C. PENNEY SURVIVOR 72
(C = 70 Ampere-Hours)

RATE	Battery # 1			Battery # 2			Battery # 3			Average	
	Time (Hrs)	Voltage	Wt Loss (gm/hr)	Time (Hrs)	Voltage	Wt Loss (gm/hr)	Time (Hrs)	Voltage	Wt Loss (gm/hr)	Voltage	Wt Loss (gm/hr)
C/33	24	15.39	9.0	24	15.42	6.0	24	16.30	7.0	15.70	7.3
	25	15.41	4.0	25	15.43	0.0	25	16.33	4.0	15.72	2.7
	26	15.42	3.0	26	15.44	4.0	26	16.34	4.0	15.73	3.7
C/40	4	15.37	4.0	4	15.39	2.0	4	16.28	4.0	15.68	3.3
	5	15.39	2.0	5	15.41	4.0	5	16.29	3.0	15.70	3.0
	6	15.39	5.0	6	15.41	8.0	6	16.28	4.0	15.69	5.7
C/50	1	15.28	2.0	1	15.29	3.0	1	16.15	3.0	15.57	2.7
	2	15.28	3.0	2	15.31	3.0	2	16.16	3.0	15.58	3.0
	3	15.29	3.0	3	15.31	3.0	3	16.15	3.0	15.58	3.0
C/67	3	15.16	1.0	1	15.15	2.0	1	15.98	1.0	15.43	1.3
	4	15.17	3.0	2	15.17	3.0	2	15.98	4.0	15.44	3.3
	5	15.17	2.0	3	15.17	1.0	3	15.98	1.0	15.44	1.3
C/100	2	14.95	1.0	2	14.95	2.0	2	15.78	2.0	15.23	1.7
	3	14.96	2.0	3	14.97	1.0	3	15.76	1.0	15.23	1.3
	4	14.96	1.0	4	14.97	1.0	4	15.76	0.0	15.23	0.7
C/200	1	14.53	1.0	2	14.54	0.0	1	15.16	0.0	14.77	0.3
	2	14.55	0.0	3	14.54	1.0	2	15.23	1.0	14.77	0.7
	3	14.55	0.0	4	14.54	1.0	3	15.25	1.0	14.78	0.7
C/100	1	15.00	2.0	1	15.00	0.0	1	15.71	0.0	15.26	0.7
	1.5	15.00	N/A	1.5	15.00	N/A	1.5	15.73	N/A	15.24	N/A
	2	15.00	0.0	2	15.00	2.0	2	15.75	0.0	15.25	0.7
C/67	1	15.23	2.0	1	15.25	2.0	1	16.00	2.0	15.49	2.0
	1.5	15.23	N/A	1.5	15.24	N/A	1.5	16.00	N/A	15.49	N/A
	2	15.23	3.0	2	15.24	2.0	2	16.00	2.0	15.49	2.3
C/50	1	15.39	3.0	1	15.40	3.0	1	16.19	3.0	15.66	3.0
	1.5	15.39	N/A	1.5	15.40	N/A	1.5	16.22	N/A	15.67	N/A
	2	15.38	2.0	2	15.40	3.0	2	16.23	4.0	15.67	3.0
C/40	1	15.50	2.0	1	15.52	3.0	1	16.48	3.0	15.83	2.7
	1.5	15.50	N/A	1.5	15.52	N/A	1.5	16.45	N/A	15.82	N/A
	2	15.50	3.0	2	15.52	3.0	2	16.44	4.0	15.82	3.3
C/33	1	15.60	4.0	1	15.63	5.0	1	16.46	3.0	15.90	4.0
	1.5	15.60	N/A	1.5	15.62	N/A	1.5	16.38	N/A	15.87	N/A
	2	15.60	6.0	2	15.62	5.0	2	16.34	5.0	15.85	5.3

N/A Not Applicable

OVERCHARGE EVALUATION TEST DATA AT -20°C
GLOBE UNION GC 12550
(C = 58 Ampere-Hours)

RATE	Battery # 1 Time (Hrs)	Voltage	Wt Loss (gm/hr)	Battery # 2 Time (Hrs)	Voltage	Wt Loss (gm/hr)	Battery # 3 Time (Hrs)	Voltage	Wt Loss (gm/hr)	Average Voltage	Average Wt Loss (gm/hr)
C/33	1	16.52	2.0	1	16.60	1.0	1	16.60	2.0	16.57	1.7
	2	16.49	5.0	2	16.56	4.0	2	16.56	2.0	16.53	3.7
	3	16.47	2.0	3	16.55	3.0	3	16.54	4.0	16.52	3.0
C/40	1	16.38	1.0	1	16.47	2.0	1	16.45	2.0	16.43	1.7
	2	16.38	2.0	2	16.47	2.0	2	16.45	2.0	16.43	2.0
	3	16.39	3.0	3	16.47	1.0	3	16.46	2.0	16.43	2.0
C/50	4	16.32	5.0	3	16.40	2.0	7	16.41	1.0	16.38	2.7
	5	16.32	2.0	4	16.40	4.0	8	16.40	1.0	16.37	2.3
	6	16.32	0.0	5	16.40	1.0	9	16.41	3.0	16.38	1.3
C/67	5	16.24	1.0	5	16.33	2.0	5	16.32	1.0	16.30	1.3
	6	16.24	1.0	6	16.33	2.0	6	16.33	3.0	16.30	2.3
	7	16.24	2.0	7	16.33	1.0	7	16.33	1.0	16.30	1.3
C/100	2	16.09	2.0	2	16.18	1.0	2	16.18	1.0	16.15	1.3
	3	16.08	0.0	3	16.16	1.0	3	16.17	5.0	16.14	2.0
	4	16.07	0.0	4	16.16	1.0	4	16.16	0.0	16.13	0.3
C/200	7	15.84	0.0	8	15.93	0.0	8	15.93	0.0	15.90	0.0
	8	15.84	0.0	9	15.93	0.0	9	15.93	0.0	15.90	0.0
	9	15.84	0.0	10	15.93	0.0	10	15.93	0.0	15.90	0.0
C/100	1	16.14	0.0	1	16.23	0.0	1	16.24	2.0	16.20	0.7
	2	16.14	2.0	2	16.22	3.0	2	16.23	0.0	16.20	1.3
	3	16.13	1.0	3	16.22	0.0	3	16.22	0.0	16.19	.3
C/67	1	16.28	1.0	1	16.37	1.0	1	16.37	1.0	16.34	1.0
	2	16.27	3.0	2	16.36	2.0	2	16.36	3.0	16.33	2.7
	3	16.26	1.0	3	16.35	1.0	3	16.35	2.0	16.32	1.3
C/50	1	16.36	2.0	1	16.45	4.0	1	16.45	2.0	16.42	2.7
	2	16.35	2.0	2	16.43	2.0	2	16.44	2.0	16.41	2.0
	3	16.34	5.0	3	16.43	4.0	3	16.43	2.0	16.40	3.7
C/40	1	16.42	1.0	1	16.50	2.0	1	16.50	3.0	16.47	2.0
	2	16.40	2.0	2	16.49	4.0	2	16.49	3.0	16.46	3.0
	3	16.40	3.0	3	16.48	0.0	3	16.48	6.0	16.45	3.0
C/33	1	16.46	4.0	1	16.54	2.0	1	16.54	1.0	16.52	2.3
	2	16.45	2.0	2	16.53	4.0	2	16.53	3.0	16.50	3.0
	3	16.44	3.0	3	16.52	2.0	3	16.52	2.0	16.49	2.3

OVERCHARGE EVALUATION TEST DATA AT 50°C
GLOBE UNION GC 12550
(C = 58 Ampere-Hours)

	Battery # 1			Battery # 2			Battery # 3			Average	
RATE	Time (Hrs)	Voltage	Wt Loss (gm/hr)	Time (Hrs)	Voltage	Wt Loss (gm/hr)	Time (Hrs)	Voltage	Wt Loss (gm/hr)	Voltage	Wt Loss (gm/hr)
	19	15.27	5.0	18	15.29	5.0	18	15.40	3.0	15.32	4.0
C/33	20	15.27	3.0	19	15.30	3.0	19	15.41	4.0	15.33	3.3
	21	15.27	3.0	20	15.30	4.0	20	15.41	4.0	15.33	3.7
	3	15.20	1.0	3	15.24	0.0	5	15.37	2.0	15.27	1.0
C/40	4	15.22	4.0	4	15.26	4.0	6	15.38	3.0	15.29	3.7
	5	15.22	1.0	5	15.26	2.0	7	15.38	4.0	15.29	2.3
	2	15.10	2.0	1	15.15	3.0	3	15.28	2.0	15.18	2.3
C/50	3	15.11	2.0	2	15.16	4.0	4	15.29	2.0	15.19	2.7
	4	15.11	2.0	3	15.16	1.0	5	15.29	1.0	15.19	1.3
	2	14.92	0.0	3	15.01	3.0	4	15.15	2.0	15.01	1.7
C/67	3	14.93	3.0	4	15.02	2.0	5	15.16	1.0	15.04	2.0
	4	14.93	1.0	5	15.02	3.0	6	15.16	2.0	15.04	2.0
	4	14.60	1.0	4	14.75	2.0	3	14.91	1.0	14.75	1.3
C/100	5	14.61	1.0	5	14.76	1.0	4	14.92	1.0	14.75	1.0
	6	14.61	0.0	6	14.76	0.0	5	14.92	1.0	14.75	0.3
	1	13.56	0.0	1	13.91	0.0	1	13.86	0.0	13.77	0.0
C/200	1.5	13.51	0.0	1.5	13.91	0.0	1.5	13.83	0.0	13.75	0.0
	2	13.50	0.0	2	13.91	0.0	2	13.80	0.0	13.74	0.0
	1	14.51	0.0	1	14.80	0.0	1	14.94	2.0	14.73	0.7
C/100	2	14.57	N/A	2	14.80	N/A	2	14.93	N/A	14.77	N/A
	3	14.55	0.0	3	14.80	0.0	3	14.93	0.0	14.76	0.0
	1	15.00	2.0	1	15.10	3.0	1	15.22	2.0	15.11	2.3
C/67	1.5	14.99	N/A	1.5	15.09	N/A	1.5	15.21	N/A	15.10	N/A
	2	14.98	2.0	2	15.09	0.0	2	15.21	3.0	15.09	1.7
	1	15.20	3.0	1	15.27	2.0	1	15.37	3.0	15.31	2.7
C/50	1.5	15.19	N/A	1.5	15.26	N/A	1.5	15.37	N/A	15.27	N/A
	2	15.19	3.0	2	15.26	4.0	2	15.36	1.0	15.27	2.7
	1	15.32	1.0	1	15.38	1.0	1	15.48	1.0	15.39	1.0
C/40	1.5	15.32	N/A	1.5	15.37	N/A	1.5	15.47	N/A	15.39	N/A
	2	15.31	3.0	2	15.36	4.0	2	15.46	2.0	15.38	3.0
	1	15.42	2.0	1	15.46	3.0	1	15.56	4.0	15.47	3.0
C/33	1.5	15.41	N/A	1.5	15.45	N/A	1.5	15.55	N/A	15.47	N/A
	2	15.40	3.0	2	15.49	2.0	2	15.54	4.0	15.46	3.0

N/A Not Applicable

OVERCHARGE EVALUATION TEST DATA AT -20°C
NIFE - NICKEL CADMIUM - L-302-2
(C = 55 Ampere-Hours)

RATE	Battery # 1			Battery # 2			Battery # 3			Average	
	Time (Hrs)	Voltage	Wt Loss (gm/hr)	Time (Hrs)	Voltage	Wt Loss (gm/hr)	Time (Hrs)	Voltage	Wt Loss (gm/hr)	Voltage	Wt Loss (gm/hr)
C/33	3	17.53	2.0	3	17.49	1.0	3	17.52	3.0	17.51	2.0
	4	17.54	0.0	4	17.51	1.0	4	17.53	1.0	17.53	0.7
	5	17.55	4.0	5	17.50	6.0	5	17.54	4.0	17.53	4.7
C/40	2	17.44	3.0	1	17.40	1.0	1	17.43	3.0	17.42	2.3
	3	17.45	4.0	2	17.39	3.0	2	17.43	1.0	17.42	2.7
	4	17.46	3.0	3	17.40	0.0	3	17.45	2.0	17.44	1.7
C/50	2	17.35	1.0	2	17.30	0.0	2	17.36	4.0	17.34	1.7
	3	17.36	3.0	3	17.31	3.0	3	17.35	2.0	17.34	2.7
	4	17.37	2.0	4	17.31	1.0	4	17.35	1.0	17.34	1.3
C/67	1	17.21	2.0	1	17.16	2.0	1	17.20	2.0	17.19	2.0
	2	17.22	1.0	2	17.16	0.0	2	17.21	3.0	17.20	1.3
	3	17.22	2.0	3	17.17	4.0	3	17.21	3.0	17.20	3.0
C/100	1	17.01	1.0	1	16.96	1.0	1	17.01	2.0	16.99	1.3
	2	17.02	2.0	2	16.96	1.0	2	17.01	0.0	17.00	1.0
	3	17.02	0.0	3	16.98	3.0	3	17.02	3.0	17.01	2.0
C/200	2	16.68	1.0	2	16.63	0.0	2	16.68	0.0	16.67	0.3
	3	16.68	1.0	3	16.63	0.0	3	16.68	0.0	16.66	0.3
	4	16.69	0.0	4	16.64	3.0	4	16.69	0.0	16.67	1.0

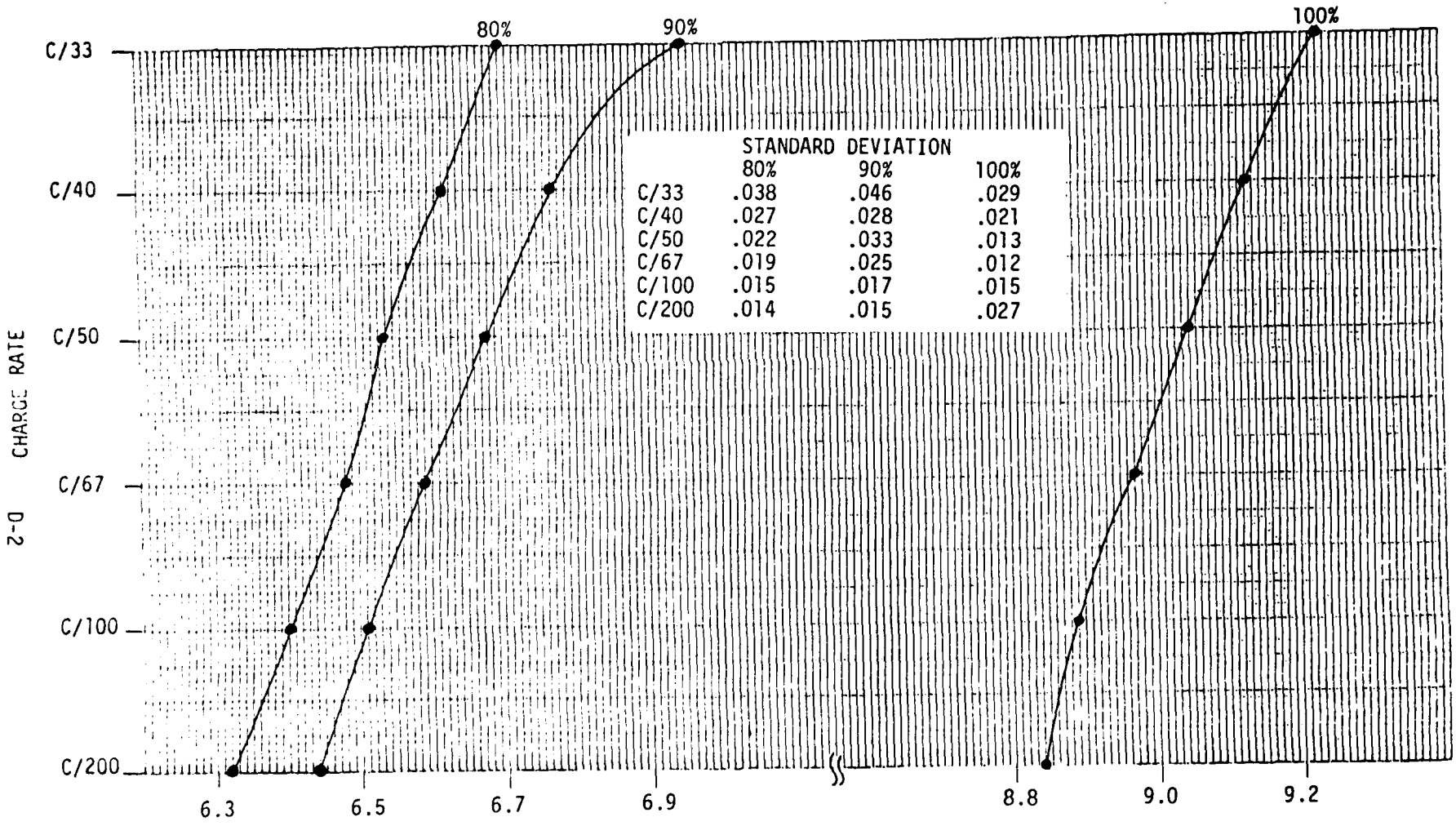
OVERCHARGE EVALUATION TEST DATA AT 50°C
NIFE - NICKEL CADMIUM - L-302-2
(C = 55 Ampere-Hours)

RATE	Battery # 1			Battery # 2			Battery # 3			Average	
	Time (Hrs)	Voltage	Wt Loss (gm/hr)	Time (Hrs)	Voltage	Wt Loss (gm/hr)	Time (Hrs)	Voltage	Wt Loss (gm/hr)	Voltage	Wt Loss (gm/hr)
C/33	16	15.00	2.0	16	14.96	2.0	16	15.00	2.0	14.99	2.0
	17	15.00	3.0	17	14.96	3.0	17	15.00	3.0	14.99	3.0
	18	15.00	2.0	18	14.96	2.0	18	15.00	4.0	14.99	2.7
C/40	1	14.91	3.0	1	14.87	3.0	1	14.91	4.0	14.90	3.3
	2	14.91	3.0	2	14.87	4.0	2	14.91	3.0	14.90	3.3
	3	14.91	3.0	3	14.87	4.0	3	14.91	3.0	14.90	3.3
C/50	2	14.81	2.0	2	14.79	4.0	2	14.81	1.0	14.80	2.3
	3	14.81	2.0	3	14.77	1.0	3	14.81	1.0	14.80	1.3
	4	14.81	3.0	4	14.77	5.0	4	14.81	2.0	14.80	3.3
C/67	1	14.67	1.0	1	14.63	3.0	1	14.67	1.0	14.66	1.7
	2	14.67	0.0	2	14.63	2.0	2	14.67	2.0	14.66	1.3
	3	14.67	2.0	3	14.63	3.0	3	14.66	0.0	14.65	1.7
C/100	1	14.48	0.0	1	14.45	3.0	1	14.48	2.0	14.47	1.7
	2	14.48	2.0	2	14.45	0.0	2	14.48	1.0	14.47	1.0
	3	14.48	2.0	3	14.46	2.0	3	14.49	2.0	14.48	2.0
C/200	8	14.23	0.0	8	14.19	0.0	8	14.23	0.0	14.21	0.0
	9	14.23	0.0	9	14.19	0.0	9	14.23	1.0	14.21	0.3
	10	14.24	1.0	10	14.20	0.0	10	14.23	0.0	14.22	0.3

APPENDIX D

STATE-OF-CHARGE EVALUATION GRAPHS

STATE-OF-CHARGE EV' UATION TEST AT-20°C
CHARGE RATE VS S1..E OF CHARGE VOLTAGE
WILLARD, MODEL DD-3-3, P/N 8241
(C = 82 Ampere-Hours)



STANDARD DEVIATION

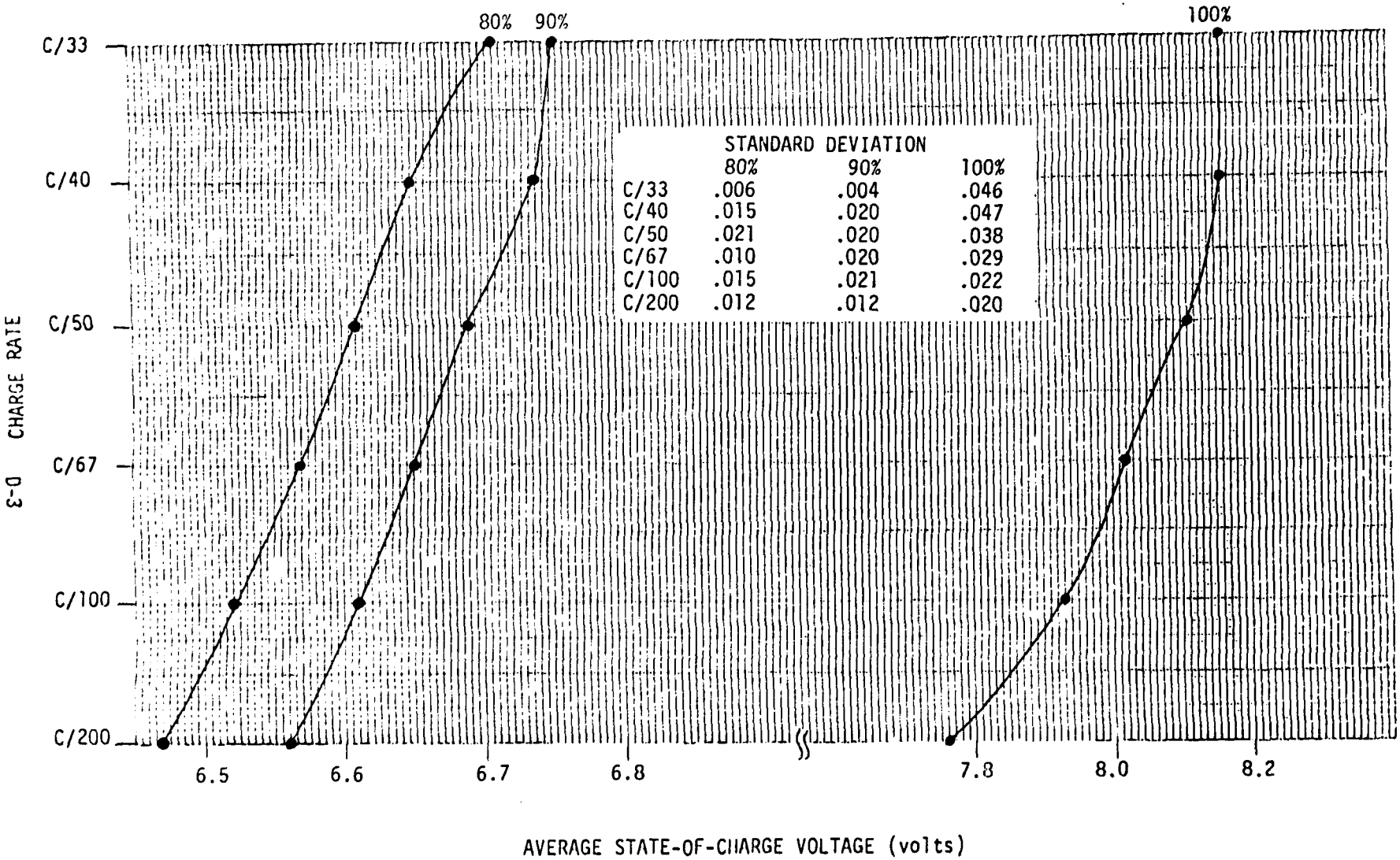
	80%	90%	100%
C/33	.038	.046	.029
C/40	.027	.028	.021
C/50	.022	.033	.013
C/67	.019	.025	.012
C/100	.015	.017	.015
C/200	.014	.015	.027

Note: Battery state-of-charge level indicated by percent

D-2

MOEC/C 83-75

STATE-OF-CHARGE EVALUATION TEST AT 50°C
CHARGE RATE VS STATE OF CHARGE VOLTAGE
WILLARD, MODEL DD-3-3, P/N 8241
(C = 82 Ampere-Hours)



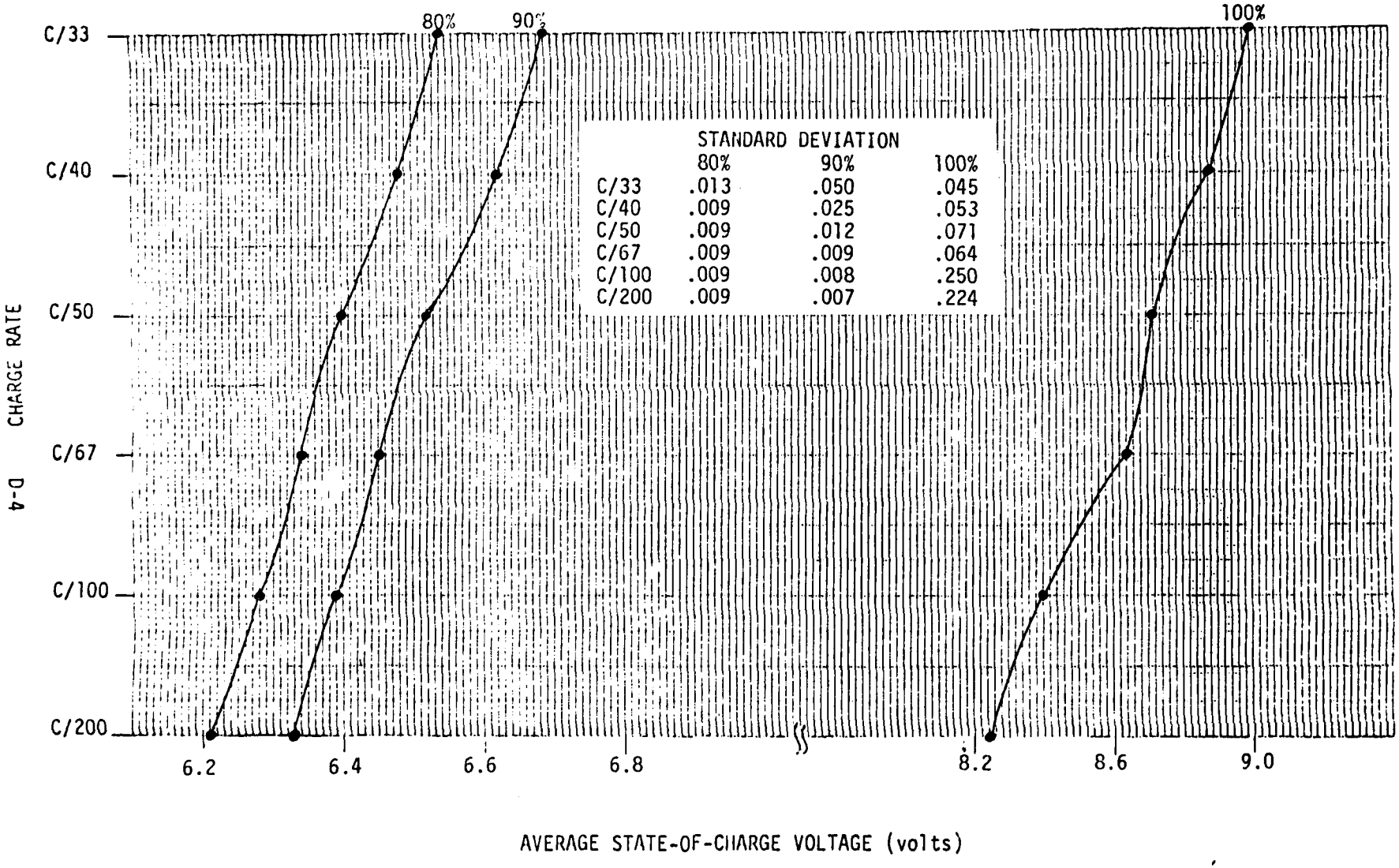
STANDARD DEVIATION

	80%	90%	100%
C/33	.006	.004	.046
C/40	.015	.020	.047
C/50	.021	.020	.038
C/67	.010	.020	.029
C/100	.015	.021	.022
C/200	.012	.012	.020

Note: Battery state-of-charge level indicated by percent

WOEC/C 83-75

STATE-OF-CHARGE EVALUATION TEST AT -20°C
CHARGE RATE VS STATE OF CHARGE VOLTAGE
WILLARD, MODEL DD-3-3, P/N 8241 (Cycled)
(C = 85 Ampere-Hours)

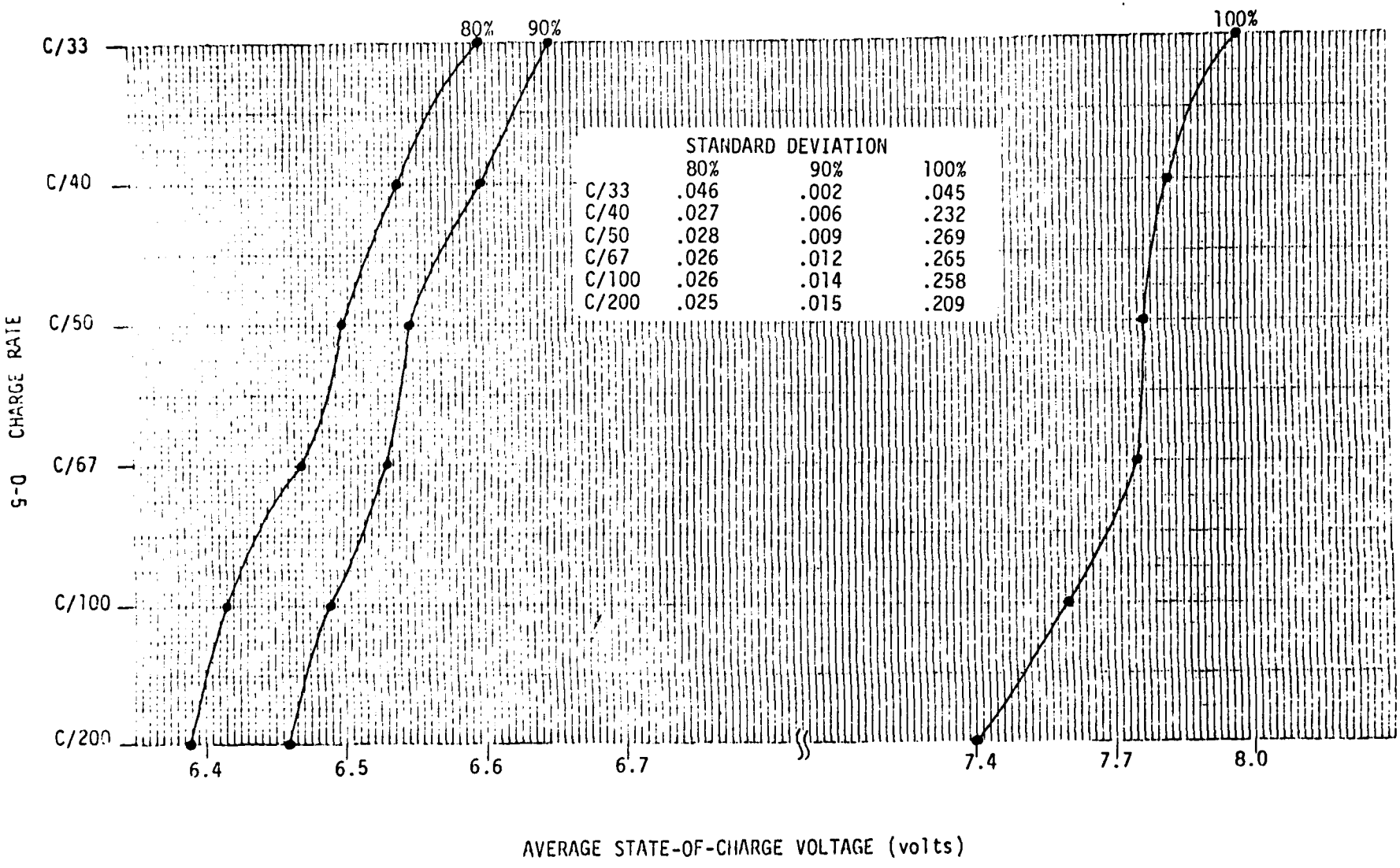


STANDARD DEVIATION

	80%	90%	100%
C/33	.013	.050	.045
C/40	.009	.025	.053
C/50	.009	.012	.071
C/67	.009	.009	.064
C/100	.009	.008	.250
C/200	.009	.007	.224

Notes: (1) Battery state-of-charge level indicated by percent
(2) Only 2 batteries shown because of erratic behavior of battery # 3

STATE-OF-CHARGE EVALUATION TEST AT 50°C
CHARGE RATE VS STATE OF CHARGE VOLTAGE
WILLARD, MODEL DD-3-3, P/N 8241 (Cycled)
(C = 85 Ampere-Hours)



STANDARD DEVIATION

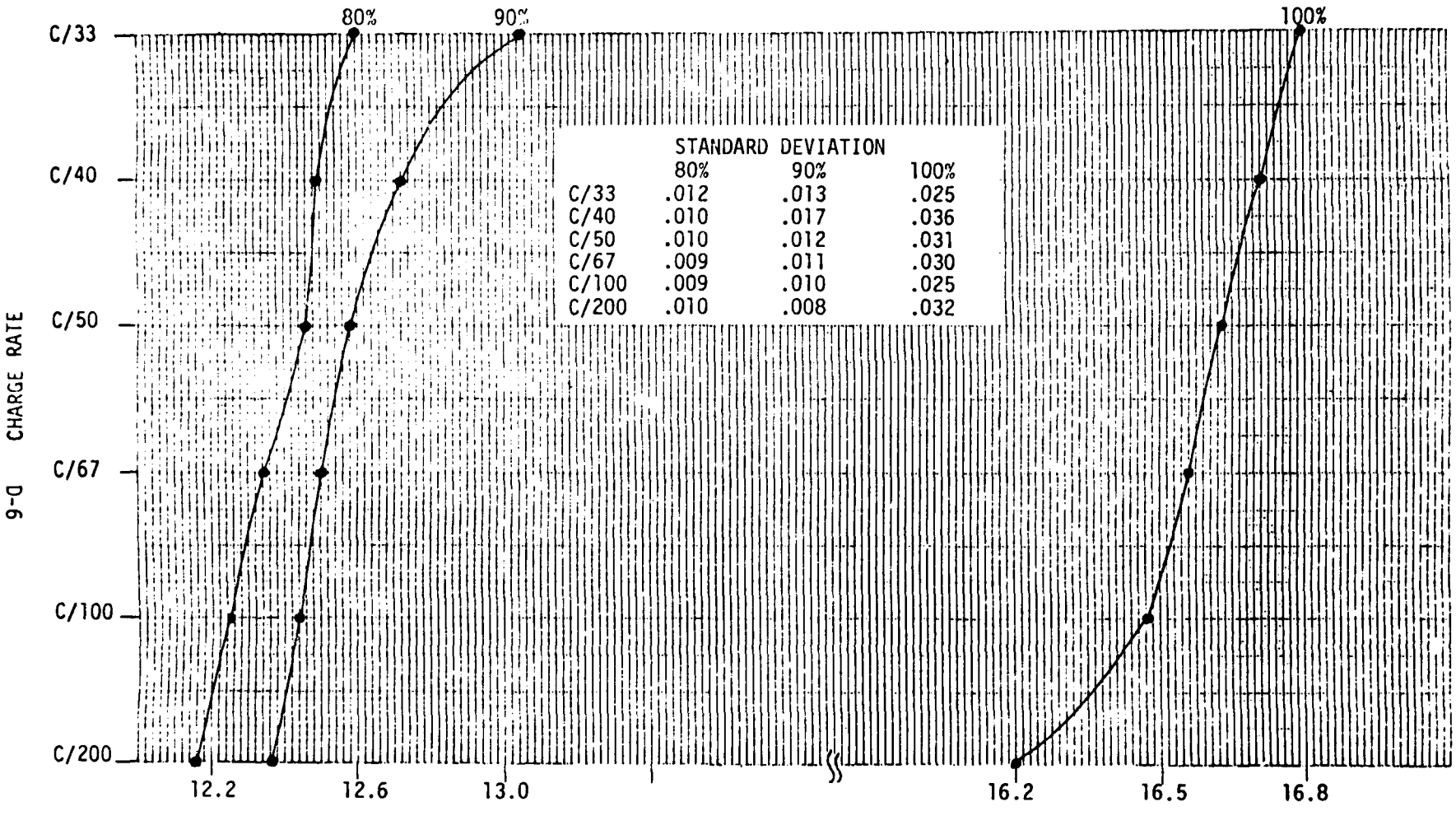
	80%	90%	100%
C/33	.046	.002	.045
C/40	.027	.006	.232
C/50	.028	.009	.269
C/67	.026	.012	.265
C/100	.026	.014	.258
C/200	.025	.015	.209

Notes: (1) Battery state-of-charge level indicated by percent
(2) Only 2 batteries shown because of erratic behavior of battery # 3

MOEC/C 83-75

STATE-OF-CHARGE EVALUATION TEST AT -20°C
CHARGE RATE VS STATE OF CHARGE VOLTAGE

DELCO-REMY 2000
(C = 93 Ampere-Hours)



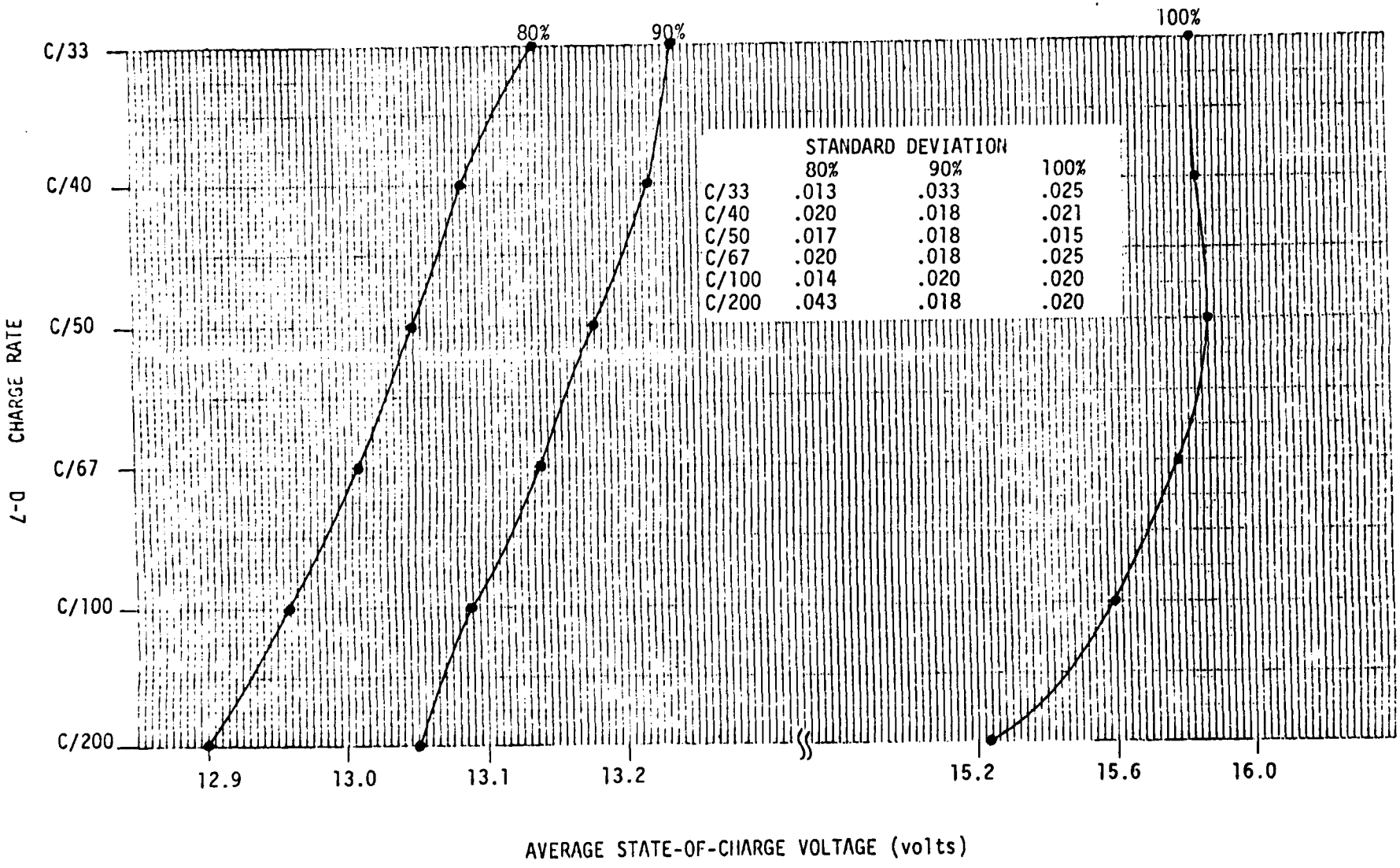
STANDARD DEVIATION

	80%	90%	100%
C/33	.012	.013	.025
C/40	.010	.017	.036
C/50	.010	.012	.031
C/67	.009	.011	.030
C/100	.009	.010	.025
C/200	.010	.008	.032

Notes: (1) Battery state-of-charge level indicated by percent
(2) State-of-charge data (80%) slightly out of line due to 58 hour stand period prior to C/50 charge.

WOEC/C 83-75

STATE-OF-CHARGE EVALUATION TEST AT 50°C
CHARGE RATE VS STATE OF CHARGE VOLTAGE
DELCO-REMY 2000
(C = 93 Ampere-Hours)



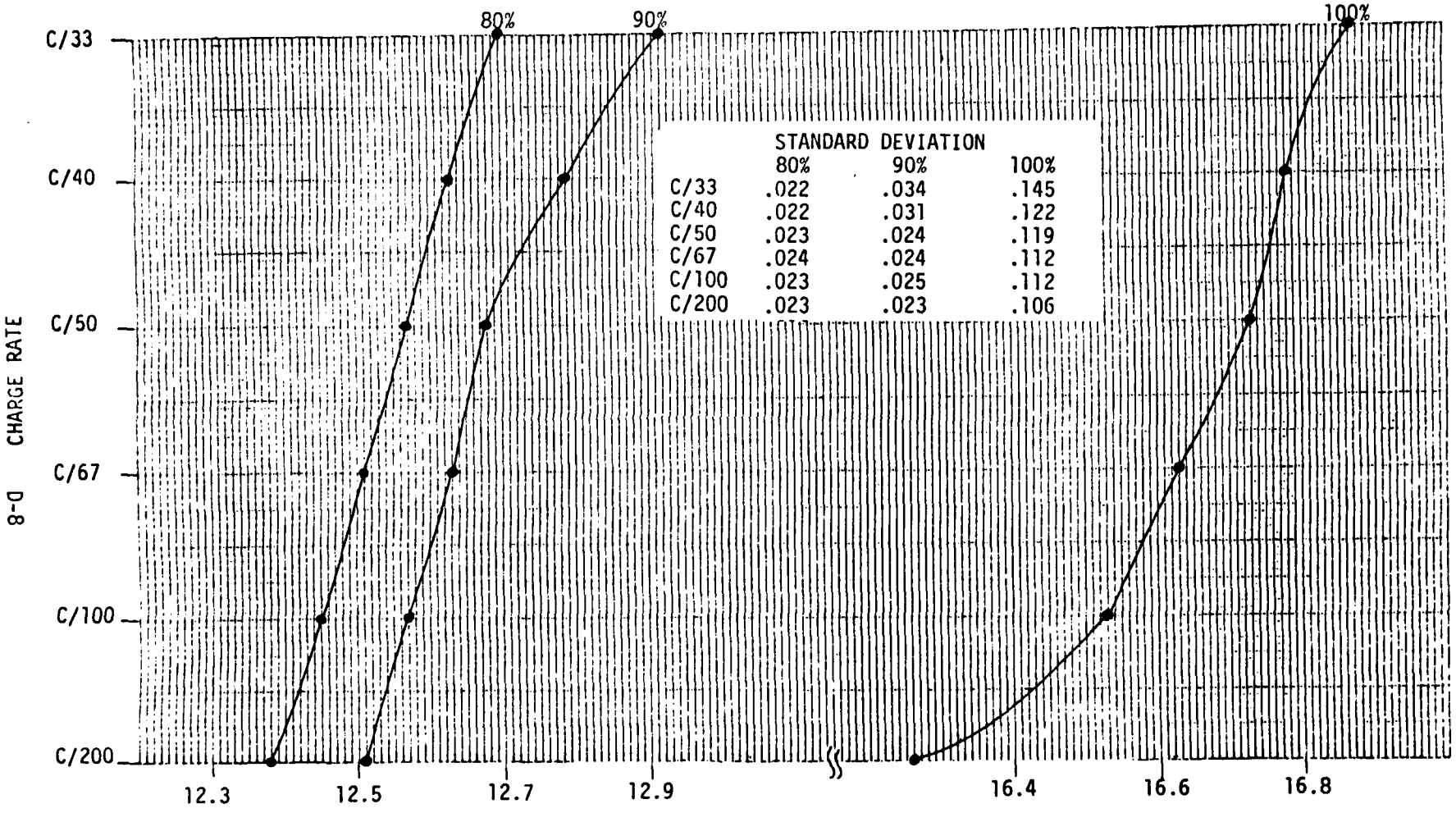
STANDARD DEVIATION

	80%	90%	100%
C/33	.013	.033	.025
C/40	.020	.018	.021
C/50	.017	.018	.015
C/67	.020	.018	.025
C/100	.014	.020	.020
C/200	.043	.018	.020

Note: Battery state-of-charge level indicated by percent

WQEC/C 83-75

STATE-OF-CHARGE EVALUATION TEST AT -20°C
CHARGE RATE VS STATE OF CHARGE VOLTAGE
J. C. PENNEY SURVIVOR 72
(C = 70 Ampere-Hours)

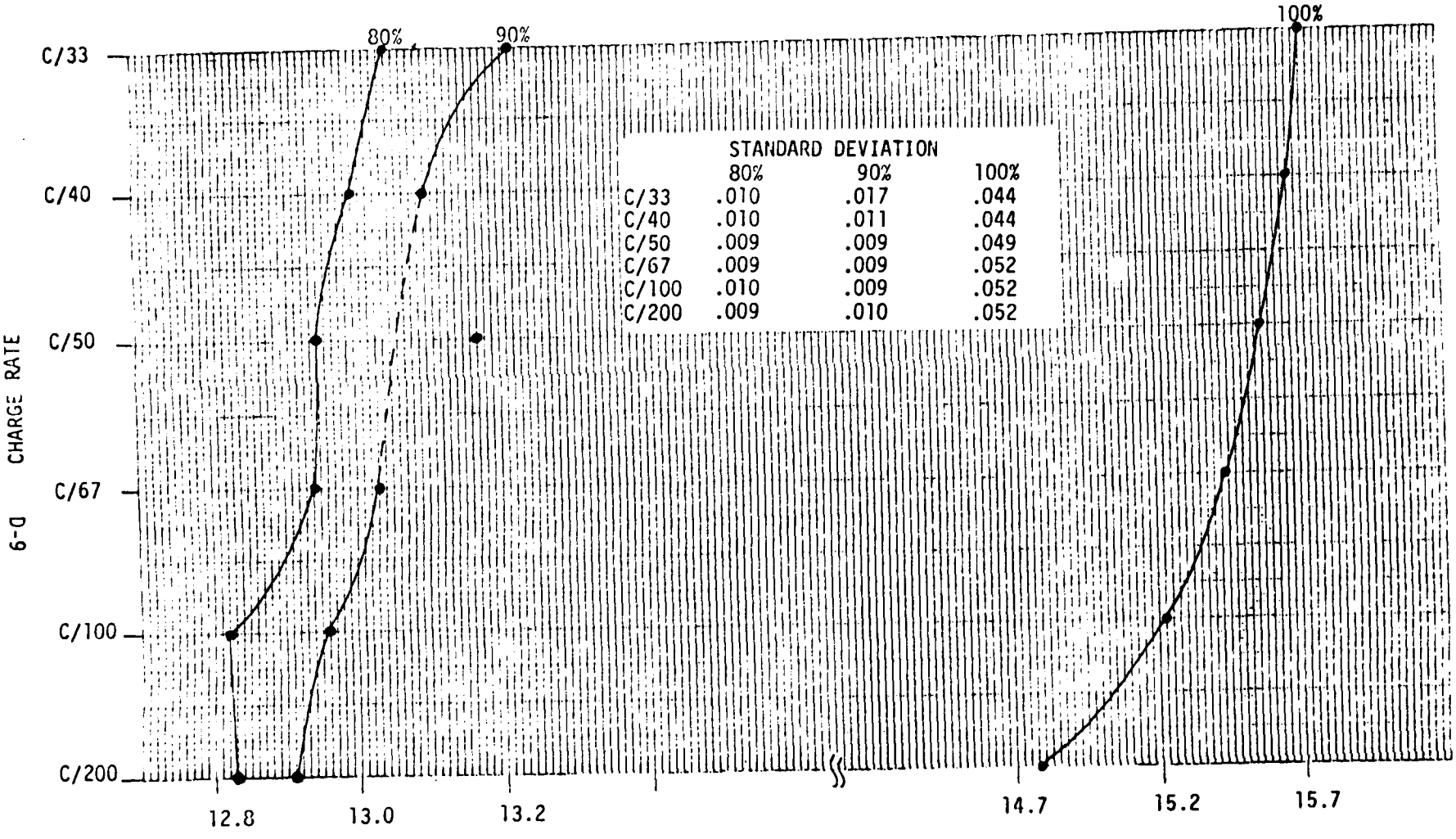


STANDARD DEVIATION

	80%	90%	100%
C/33	.022	.034	.145
C/40	.022	.031	.122
C/50	.023	.024	.119
C/67	.024	.024	.112
C/100	.023	.025	.112
C/200	.023	.023	.106

Note: Battery stat-of-charge level indicated by percent

STATE-OF-CHARGE EVALUATION TEST AT 50°C
CHARGE RATE VS STATE OF CHARGE VOLTAGE
J. C. PENNEY SURVIVOR 72
(C = 70 Ampere-Hours)



STANDARD DEVIATION

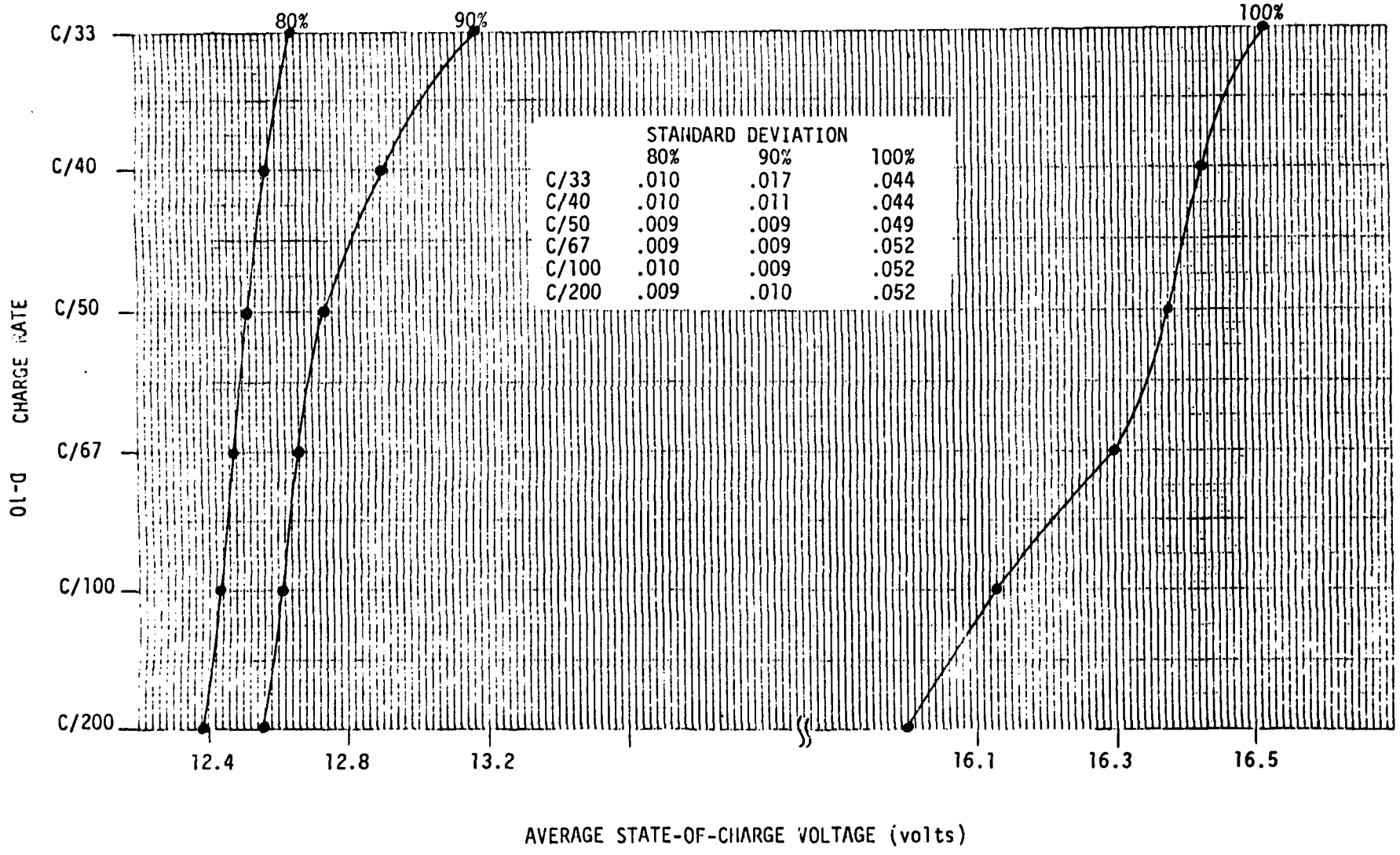
	80%	90%	100%
C/33	.010	.017	.044
C/40	.010	.011	.044
C/50	.009	.009	.049
C/67	.009	.009	.052
C/100	.010	.009	.052
C/200	.009	.010	.052

Notes: (1) Battery state-of-charge level indicated by percent
(2) Graph variations due to the erratic behavior of battery # 3

WOEC/C 83-75

STATE-OF-CHARGE EVALUATION TEST AT -20°C
CHARGE RATE VS STATE OF CHARGE VOLTAGE

GLOBE UNION GC 12550
(C = 58 Ampere-Hours)



STANDARD DEVIATION

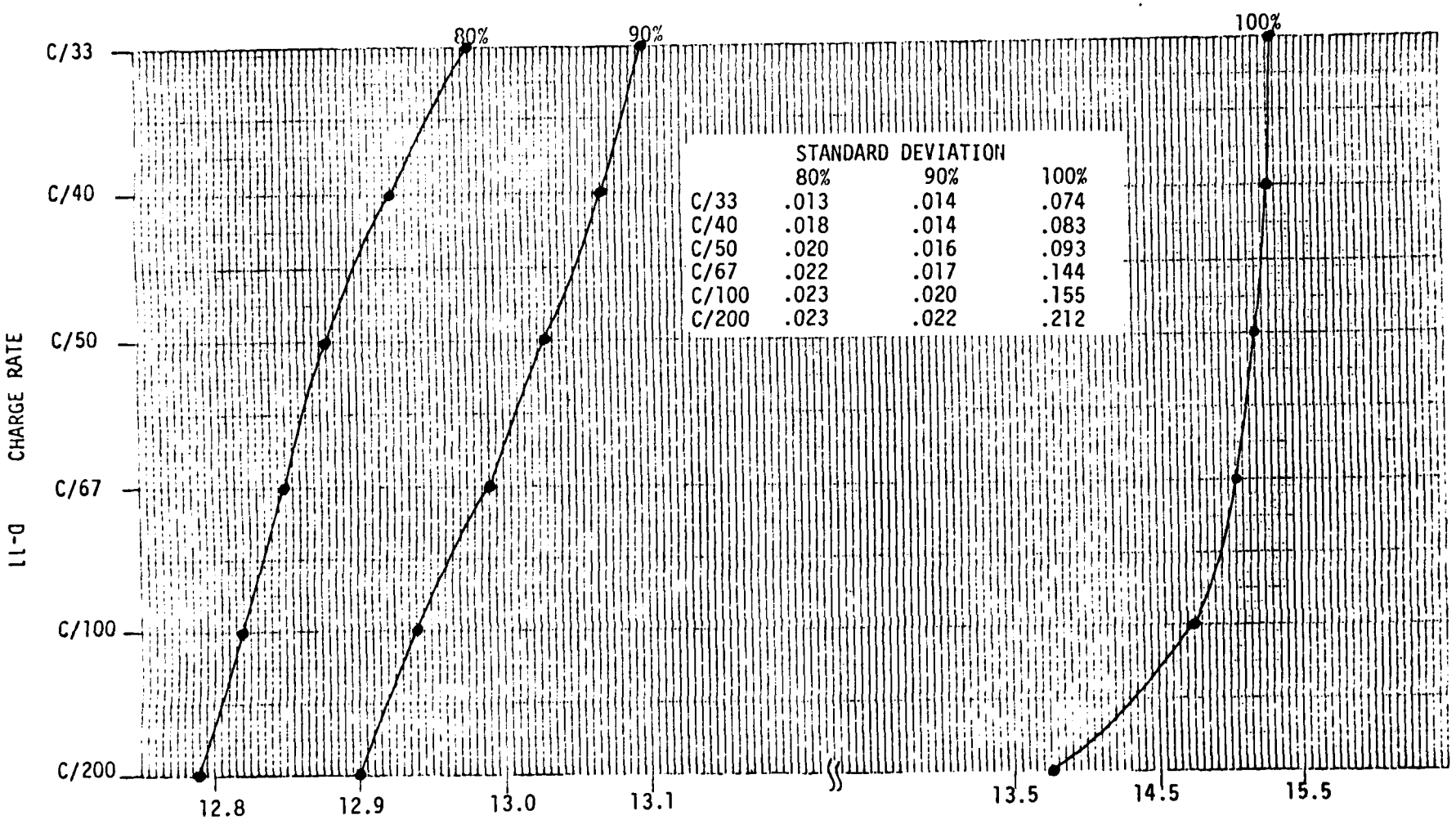
	80%	90%	100%
C/33	.010	.017	.044
C/40	.010	.011	.044
C/50	.009	.009	.049
C/67	.009	.009	.052
C/100	.010	.009	.052
C/200	.009	.010	.052

Note: Battery state-of-charge level indicated by percent

HQEC/C 83-75

STATE-OF-CHARGE EVALUATION TEST AT 50°C
CHARGE RATE VS STATE OF CHARGE VOLTAGE

GLOBE UNION GC 12550
(C = 58 Ampere-Hours)

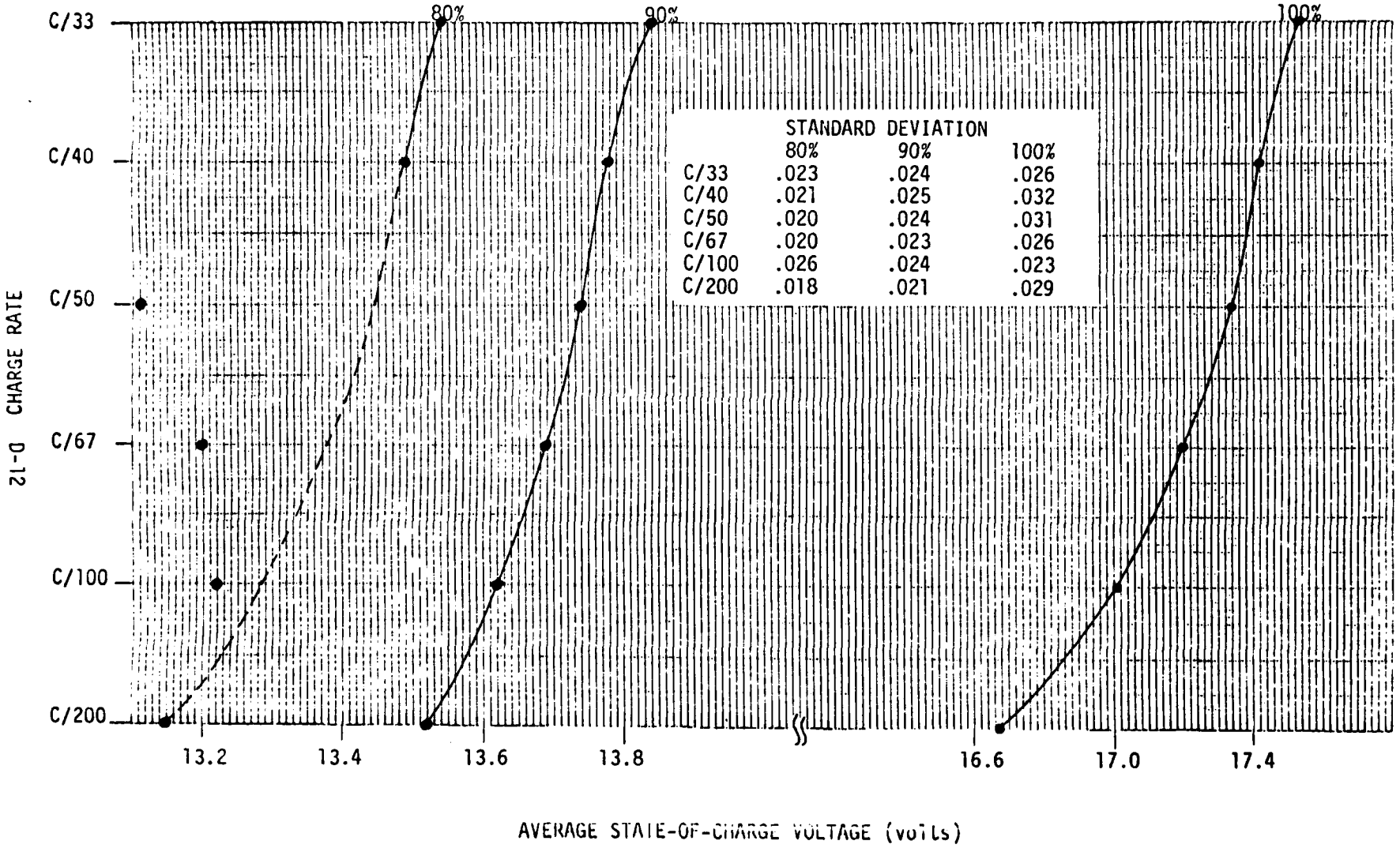


STANDARD DEVIATION

	80%	90%	100%
C/33	.013	.014	.074
C/40	.018	.014	.083
C/50	.020	.016	.093
C/67	.022	.017	.144
C/100	.023	.020	.155
C/200	.023	.022	.212

Note: Battery state-of-charge level indicated by percent

STATE-OF-CHARGE EVALUATION TEST AT -20°C
CHARGE RATE VS STATE OF CHARGE VOLTAGE
NIFE - NICKEL-CADMIUM - L-302-2
(C = 55 Ampere-Hours)



STANDARD DEVIATION

	80%	90%	100%
C/33	.023	.024	.026
C/40	.021	.025	.032
C/50	.020	.024	.031
C/67	.020	.023	.026
C/100	.026	.024	.023
C/200	.018	.021	.029

Notes: (1) Battery state -of-charge level indicated by percent
(2) State-of-charge data (80%) erratic due to 58 hour stand period prior to C/50 charge.

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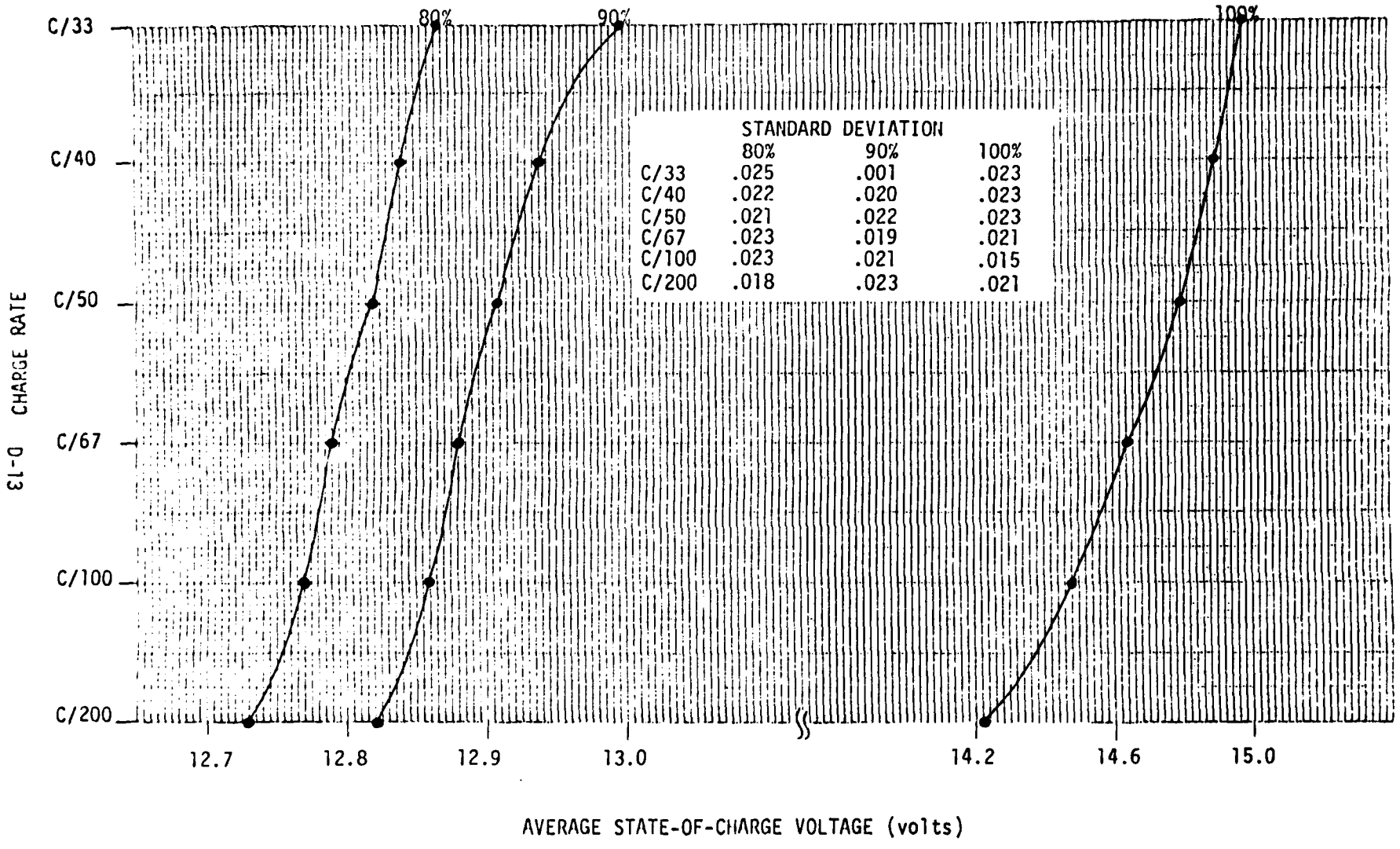
MDEC/C 83-75

STATE-OF-CHARGE EVALUATION TEST AT 50°C
CHARGE RATE VS STATE OF CHARGE VOLTAGE
NIFE - NICKEL-CADMIUM - L-302-2
(C_{55} Ampere-Hours)



STANDARD DEVIATION

	80%	90%	100%
C/33	.025	.001	.023
C/40	.022	.020	.023
C/50	.021	.022	.023
C/67	.023	.019	.021
C/100	.023	.021	.015
C/200	.018	.023	.021

Note: Battery state-of-charge level indicated by percent

APPENDIX E

STATE-OF-CHARGE EVALUATION TEST DATA

STATE-OF-CHARGE EVALUATION TEST DATA AT -20°C

Willard, Model DD-3-3, P/N 8241
(C = 82 Ampere-Hours)

Condition*	Rate	Time (Hrs)	Ampere Hours	Battery Voltages #1	#2	#3	Avg.	Battery** Water Loss (gr #1	#2	#3
1. EOD	C/100	10.0	8.33	6.30	6.29	6.25	6.28	1	-	-
SOC	C/33			6.96	6.89	6.98	6.95			
EOC	C/33	3.3	8.21	9.22	9.16	9.21	9.20	4	4	5
EOS		12.0		6.69	6.67	6.65	6.67	-	-	-
2. EOD	C/100	10.0	8.40	6.26	6.26	6.22	6.25	-	-	-
SOC	C/40			6.79	6.74	6.79	6.77			
EOC	C/40	4.0	8.14	9.13	9.06	9.09	9.09	2	2	2
EOS		12.0		6.67	6.65	6.63	6.65	-	-	1
3. EOD	C/100	10.0	8.35	6.26	6.25	6.21	6.25	-	1	1
SOC	C/50			6.69	6.65	6.71	6.68			
EOC	C/50	5.0	8.13	9.03	8.96	9.01	9.00	5	2	1
EOS		12.0		6.66	6.64	6.63	6.64			
4. EOD	C/100	10.0	8.42	6.25	6.23	6.19	6.26	-	-	-
SOC	C/67			6.60	6.57	6.61	6.59			
EOC	C/67	6.7	8.13	8.90	8.84	8.83	8.86	2	2	2
EOS		12.0		6.66	6.64	6.62	6.64	-	-	-
5. EOD	C/100	10.0	8.43	6.24	6.23	6.19	6.26	-	1	-
SOC	C/100			6.53	6.50	6.50	6.51			
EOC	C/100	10.0	8.15	8.75	8.69	8.69	8.71	-	1	-
EOS		12.0		6.67	6.64	6.63	6.65	-	-	-
6. EOD	C/100	10.0	8.36	6.23	6.22	6.18	6.21	1	2	1
SOC	C/200			6.46	6.43	6.44	6.44			
EOC	C/200	20.0	8.00	7.50	7.45	7.44	7.46	1	2	1
EOS		12.0		6.67	6.64	6.63	6.65	-	-	-
7. EOD	C/100	20.0	16.70	6.17	6.16	6.13	6.15	1	-	2
SOC	C/33			6.71	6.66	6.74	6.70			
EOC	C/33	6.6	16.37	9.18	9.11	9.13	9.14	-	2	-
EOS		12.0		6.66	6.64	6.63	6.64	-	-	-
8. EOD	C/100	20.0	16.40	6.15	6.14	6.11	6.13	-	-	-
SOC	C/40			6.63	6.59	6.64	6.62			
EOC	C/40	8.0	16.32	9.07	9.00	9.02	9.03	-	-	-
EOS		12.0		6.66	6.63	6.62	6.64	1	-	2
9. EOD	C/100	20.0	16.78	6.12	6.12	6.08	6.11	-	-	-
SOC	C/50			6.55	6.51	6.55	6.54			
EOC	C/50	10.0	16.23	8.92	8.87	8.88	8.89	-	1	1
EOS		12.0		6.65	6.63	6.61	6.63	-	-	-
10. EOD	C/100	20.0	16.77	6.08	6.07	6.04	6.06	-	-	-
SOC	C/67			6.49	6.45	6.48	6.48			
EOC	C/67	13.4	16.18	8.90	8.84	8.85	8.86	-	1	-
EOS		12.0		6.66	6.64	6.62	6.64	-	-	-
11. EOD	C/100	20.0	16.74	6.06	6.06	6.02	6.04	1	1	1
SOC	C/100			6.41	6.38	6.40	6.40			
EOC	C/100	20.0	16.05	8.65	8.60	8.59	8.61	-	1	-
EOS		12.0		6.65	6.63	6.62	6.63	1	-	-
12. EOD	C/100	20.0	16.82	6.06	6.05	6.02	6.04	1	2	0
SOC	C/200			6.33	6.31	6.31	6.32			
EOC	C/200	40.0	16.05	7.38	7.35	7.34	7.36	1	-	1
EOS		12.0		6.65	6.63	6.61	6.63	-	-	-

* Conditions 1-6 are at the 90 percent level and 7-12 are at the 80 percent level.
** Total loss during indicated time period.

EOD - End-of-discharge
SOC - Start-of-charge
EOC - End-of-charge
EOS - End-of-stand

STATE-OF-CHARGE EVALUATION TEST DATA AT 50°C

Willard, Model DU-3-3, P/N 8241
(C = 62 Ampere-Hours)

Condition*	Rate	Time (Hrs)	Ampere Hours	Battery Voltages #1	#2	#3	Avg.	Battery** Water Loss (gm) #1	#2	#3
1. EOD	C/100	10.0	8.25	6.49	6.46	6.46	6.47	2	2	-
SOC	C/33			6.77	6.78	6.77	6.77			
EOC	C/33	3.3	8.10	7.98	8.10	7.98	8.02	1	-	-
EOS		12.0		6.64	6.63	6.61	6.63	1	2	-
2. EOD	C/100	10.0	8.25	6.49	6.45	6.46	6.47	1	3	-
SOC	C/40			6.74	6.76	6.72	6.74			
EOC	C/40	4.0	8.17	7.86	7.90	7.86	7.87	1	1	-
EOS		12.0		6.64	6.63	6.61	6.63	3	2	-
3. EOD	C/100	10.0	8.10	6.48	6.45	6.45	6.46	-	2	-
SOC	C/50			6.70	6.71	6.68	6.69			
EOC	C/50	5.0	8.12	7.73	7.77	7.73	7.74	1	1	-
EOS		12.0		6.64	6.63	6.61	6.63	-	3	-
4. EOD	C/100	10.0	8.25	6.47	6.44	6.44	6.45	1	1	-
SOC	C/67			6.65	6.67	6.63	6.65			
EOC	C/67	6.7	8.06	7.32	7.48	7.49	7.43	2	2	-
EOS		12.0		6.64	6.62	6.61	6.62	1	1	-
5. EOD	C/100	10.0	8.31	6.47	6.39	6.44	6.43	-	1	-
SOC	C/100			6.61	6.63	6.59	6.61			
EOC	C/100	10.0	8.00	6.91	6.95	6.92	6.93	1	2	-
EOS		12.0		6.63	6.62	6.61	6.62	1	2	2
6. EOD	C/100	10.0	8.36	6.46	6.42	6.43	6.44	-	1	-
SOC	C/200			6.57	6.56	6.55	6.56			
EOC	C/200	20.0	8.00	6.80	6.79	6.79	6.79	2	3	2
EOS		12.0		6.62	6.61	6.60	6.61	-	-	-
7. EOD	C/100	20.0	16.53	6.41	6.38	6.39	6.39	4	2	3
SOC	C/33			6.71	6.71	6.70	6.71			
EOC	C/33	6.6	16.32	7.82	7.82	7.81	7.82	-	2	-
EOS		12.0		6.63	6.62	6.60	6.62	3	1	0
8. EOD	C/100	20.0	16.50	6.40	6.40	6.40	6.40	-	-	-
SOC	C/40			6.67	6.65	6.64	6.65			
EOC	C/40	8.0	16.29	7.62	7.64	7.62	7.63	-	-	-
EOS		12.0		6.62	6.61	6.60	6.61	1	-	-
9. EOD	C/100	20.0	16.24	6.39	6.39	6.39	6.39	3	3	-
SOC	C/50			6.63	6.60	6.59	6.61			
EOC	C/50	10.0	16.23	7.12	7.15	7.13	7.13	1	-	-
EOS		12.0		6.62	6.61	6.60	6.61	2	1	-
10. EOD	C/100	20.0	17.00	6.38	6.38	6.39	6.38	-	3	-
SOC	C/67			6.58	6.56	6.57	6.57			
EOC	C/67	13.4	16.20	6.96	6.99	6.97	6.97	-	-	1
EOS		12.0		6.61	6.60	6.59	6.60	-	-	-
11. EOD	C/100	20.0	16.53	6.37	6.32	6.36	6.35	-	-	-
SOC	C/100			6.53	6.52	6.50	6.52			
EOC	C/100	20.0	16.01	6.87	6.86	6.87	6.87	1	2	-
EOS		12.0		6.60	6.60	6.59	6.60	-	2	-
12. EOD	C/100	20.0	16.54	6.36	6.34	6.35	6.35	2	-	2
SOC	C/200			6.48	6.48	6.46	6.47			
EOC	C/200	40.0	16.05	6.78	6.78	6.77	6.78	1	3	-
EOS		12.0		6.59	6.58	6.57	6.58	1	-	1

* Conditions 1-6 are at the 90 percent level and 7-12 are at the 80 percent level.
** Total loss during indicated time period.

EOD - End-of-discharge
SOC - Start-of-charge
EOC - End-of-charge
EOS - End-of-stand

STATE-OF-CHARGE EVALUATION TEST DATA AT -20°C

Willard, Model DD-3-3, P/N 8241 (Cycled)
(C = 85 Ampere-Hours)

Condition*	Rate	Time (Hrs)	Ampere Hours	Battery Voltages #1	#2	#3	Avg.	Battery** Water Loss (gm #1	#2	#3
1. EOD	C/100	10.0	8.96	6.22	6.64	6.17	6.34	-	1	1
SOC	C/33			6.72	6.64	6.64	6.69			
EOC	C/33	3.3	8.54	9.01	9.12	8.41	8.85	3	6	3
EOS		12.0		6.57	6.79	6.43	6.60	1	1	-
2. EOD	C/100	10.0	8.50	6.20	6.22	6.14	6.19	-	-	-
SOC	C/40			6.64	6.67	6.56	6.62			
EOC	C/40	4.0	8.95	8.93	9.10	7.98	8.67	2	3	1
EOS		12.0		6.56	6.59	6.44	6.53	-	-	-
3. EOD	C/100	10.0	8.50	6.19	6.20	6.13	6.17	1	1	1
SOC	C/50			6.54	6.56	6.46	6.52			
EOC	C/50	5.0	8.60	8.80	9.02	7.87	8.56	2	2	2
EOS		12.0		6.56	6.58	6.45	6.53	1	-	-
4. EOD	C/100	10.0	8.50	6.18	6.19	6.11	6.16	-	-	-
SOC	C/67			6.47	6.48	6.39	6.45			
EOC	C/67	6.7	8.57	8.69	8.92	7.84	8.48	1	1	1
EOS		12.0		6.56	6.58	6.47	6.54	-	-	-
5. EOD	C/100	10.0	8.62	6.17	6.17	6.11	6.15	-	-	-
SOC	C/100			6.41	6.42	6.33	6.39			
EOC	C/100	10.0	8.88	8.51	8.80	7.68	8.33	1	1	1
EOS		12.0		6.57	6.58	6.48	6.54	-	-	-
6. EOD	C/100	10.0	8.66	6.17	6.17	6.11	6.15	-	1	1
SOC	C/200			6.35	6.36	6.27	6.33			
EOC	C/200	20.0	8.40	7.42	8.37	7.11	7.63	1	2	2
EOS		12.0		6.57	6.58	6.49	6.55	-	-	-
7. EOD	C/100	20.0	17.07	6.11	6.12	6.17	6.13	-	1	1
SOC	C/33			6.56	6.58	6.48	6.54			
EOC	C/33	6.6	16.95	8.99	9.13	8.13	8.75	2	1	2
EOS		12.0		6.57	6.58	6.43	6.53	-	-	-
8. EOD	C/100	20.0	17.00	6.08	6.09	6.01	6.06	-	-	-
SOC	C/40			6.50	6.51	6.42	6.48			
EOC	C/40	8.0	17.00	8.89	9.03	7.86	8.59	-	-	-
EOS		12.0		6.56	6.57	6.44	6.52	1	1	-
9. EOD	C/100	20.0	17.50	6.06	6.07	5.99	6.04	1	1	1
SOC	C/50			6.43	6.44	6.34	6.40			
EOC	C/50	10.0	16.83	8.76	8.92	7.76	8.48	-	-	-
EOS		12.0		6.56	6.56	6.44	6.52	-	-	-
10. EOD	C/100	20.0	16.85	6.02	6.02	5.94	5.99	-	-	-
SOC	C/67			6.37	6.38	6.28	6.34			
EOC	C/67	13.4	16.92	8.74	8.89	7.74	8.46	-	1	-
EOS		12.0		6.56	6.57	6.45	6.53	-	-	-
11. EOD	C/100	20.0	17.27	6.01	6.02	5.93	5.99	-	-	-
SOC	C/100			6.31	6.32	6.22	6.28			
EOC	C/100	20.0	16.51	8.51	8.68	7.61	8.27	-	-	-
EOS		12.0		6.56	6.57	6.46	6.53	-	-	-
12. EOD	C/100	20.0	17.05	6.01	6.01	5.93	5.98	1	-	1
SOC	C/200			6.24	6.25	6.15	6.21			
EOC	C/200	40.0	16.60	7.31	7.39	7.01	7.24	-	-	-
EOS		12.0		6.56	6.56	6.47	6.53	-	-	-

* Conditions 1-6 are at the 90 percent level and 7-12 are at the 8[illegible] percent level.
** Total loss during indicated time period.

EOD - End-of-discharge
SOC - Start-of-charge
EOC - End-of-charge
EOS - End-of-stand

STATE-OF-CHARGE EVALUATION TEST DATA AT 50°C

Willard, Model DC-3-3, P/N 8241 (Cycled)
(C = 85 Ampere-Hours)

Condition*	Rate	Time (Hrs)	Ampere Hours	Battery Voltages #1	#2	#3	Avg.	Battery** Water Loss (gm. #1	#2	#3
1. EOD	C/100	10.0	8.60	6.41	6.41	6.35	6.39	-	5	2
SOC	C/33			6.66	6.67	6.61	6.65			
EOC	C/33	3.3	8.55	7.66	8.09	7.36	7.70	-	1	-
EOS		12.0		6.53	6.55	6.46	6.51	2	5	1
2. EOD	C/100	10.0	8.95	6.40	6.40	6.35	6.38	-	1	-
SOC	C/40			6.62	6.63	6.56	6.60			
EOC	C/40	4.0	8.37	7.09	7.32	7.02	7.14	-	1	-
EOS		12.0		6.53	6.55	6.46	6.51	-	4	1
3. EOD	C/100	10.0	8.60	6.40	6.40	6.34	6.38	-	3	1
SOC	C/50			6.58	6.59	6.49	6.55			
EOC	C/50	5.0	8.45	7.01	7.19	6.96	7.05	1	2	1
EOS		12.0		6.52	6.54	6.46	6.51	-	2	1
4. EOD	C/100	10.0	7.88	6.40	6.40	6.34	6.38	-	3	1
SOC	C/67			6.54	6.56	6.46	6.53			
EOC	C/67	6.7	8.38	6.97	7.14	7.03	7.05	1	2	2
EOS		12.0		6.52	6.55	6.46	6.51	-	4	2
5. EOD	C/100	10.0	8.72	6.38	6.40	6.33	6.37	-	1	-
SOC	C/100			6.50	6.52	6.45	6.49			
EOC	C/100	10.0	8.51	6.81	6.90	6.78	6.83	-	1	-
EOS		12.0		6.52	6.54	6.45	6.50	-	-	-
6. EOD	C/100	10.0	8.48	6.38	6.39	6.33	6.37	-	1	-
SOC	C/200			6.47	6.49	6.41	6.46			
EOC	C/200	20.0	8.47	6.70	6.76	6.63	6.70	-	4	-
EOS		12.0		6.51	6.54	6.45	6.50	-	2	1
7. EOD	C/100	20.0	17.04	6.34	6.36	6.29	6.33	1	5	2
SOC	C/33			6.60	6.66	6.54	6.60			
EOC	C/33	6.6	17.05	7.25	7.49	7.18	7.31	-	1	-
EOS		12.0		6.51	6.54	6.45	6.50	2	3	1
8. EOD	C/100	20.0	17.44	6.33	6.36	6.28	6.32	-	4	-
SOC	C/40			6.55	6.59	6.49	6.54			
EOC	C/40	8.0	17.14	7.02	7.18	7.10	7.10	4	-	1
EOS		12.0		6.51	6.55	6.44	6.50	-	4	-
9. EOD	C/100	20.0	16.51	6.33	6.36	6.28	6.32	-	-	2
SOC	C/50			6.51	6.55	6.45	6.50			
EOC	C/50	10.0	16.83	6.97	7.12	7.03	7.05	-	-	-
EOS		12.0		6.52	6.55	6.44	6.50	1	3	-
10. EOD	C/100	20.0	17.19	6.32	6.35	6.27	6.31	2	-	-
SOC	C/67			6.48	6.51	6.41	6.47			
EOC	C/67	13.4	16.72	6.86	6.96	6.81	6.88	-	3	1
EOS		12.0		6.51	6.55	6.43	6.50	-	3	-
11. EOD	C/100	20.0	17.02	6.32	6.35	6.26	6.30	-	2	-
SOC	C/100			6.44	6.48	6.37	6.43			
EOC	C/100	20.0	16.89	6.78	6.86	6.71	6.78	1	3	2
EOS		12.0		6.51	6.54	6.43	6.50	5	-	-
12. EOD	C/100	20.0	17.00	6.31	6.34	6.25	6.30	-	-	-
SOC	C/200			6.40	6.44	6.33	6.39			
EOC	C/200	40.0	17.40	6.73	6.79	6.64	6.72	9	8	-
EOS		12.0		6.51	6.54	6.42	6.49	-	4	-

* Conditions 1-6 are at the 90 percent level and 7-12 are at the 80 percent level.
** Total loss during indicated time period.

EOD - End-of-discharge
SOC - Start-of-charge
EOC - End-of-charge
EOS - End-of-stand

STATE-OF-CHARGE EVALUATION TEST DATA AT -20°F
DELCO-REMY 2000
(C = 93 Ampere-Hours)

Condition*	Rate	Time (Hrs)	Ampere Hours	Battery Voltages #1	#2	#3	Avg.	Battery** Water Loss (gm) #1	#2	#3
1. EOD	C/100	10.0	9.53	12.26	12.25	12.25	12.2	1	6	-
SOC	C/33			13.06	13.04	13.06	13.0			
EOC	C/33	5.8	16.35	16.76	16.82	16.79	16.7	16	24	18
EOS		12.0		13.18	13.10	13.16	13.1	-	-	-
2. EOD	C/100	10.0	9.49	12.16	12.15	12.17	12.1	-	-	-
SOC	C/40			12.73	12.70	12.72	12.7			
EOC	C/40	7.0	16.29	16.73	16.77	16.75	16.7	15	14	13
EOS		12.0		13.16	13.10	13.14	13.1	-	1	-
3. EOD	C/100	10.0	9.49	12.13	12.12	12.14	12.13	-	-	-
SOC	C/50			12.59	12.57	12.59	12.58			
EOC	C/50	8.8	16.29	16.68	16.73	16.70	16.7	7	13	3
EOS		12.0		13.17	13.14	13.16	13.1	-	3	-
4. EOD	C/100	10.0	9.49	12.12	12.12	12.12	12.1	4	-	1
SOC	C/67			12.50	12.49	12.51	12.5			
EOC	C/67	11.7	16.22	16.61	16.66	16.64	16.6	10	8	7
EOS		12.0		13.22	13.19	13.21	13.2	2	2	-
5. EOD	C/100	10.0	9.50	12.12	12.11	12.13	12.1	-	-	-
SOC	C/100			12.44	12.43	12.45	12.44			
EOC	C/100	15.0	13.87	16.51	16.54	16.53	16.5	4	11	5
EOS		12.0		13.24	13.21	13.23	13.23	2	-	3
6. EOD	C/100	10.0	9.51	12.12	12.12	12.13	12.1	2	3	-
SOC	C/200			12.36	12.36	12.38	12.3			
EOC	C/200	26.3	11.83	16.27	16.29	16.28	16.28	3	16	2
EOS		12.0		13.28	13.25	13.27	13.27	-	-	-
7. EOD	C/100	20.0	19.01	12.01	12.02	12.04	12.02	-	-	-
SOC	C/33			12.60	12.59	12.61	12.60			
EOC	C/33	9.1	25.44	16.86	16.92	16.88	16.89	5	23	17
EOS		12.0		13.21	13.19	13.20	13.20	6	-	-
8. EOD	C/100	20.0	18.97	11.98	11.99	12.00	11.99	4	-	-
SOC	C/40			12.49	12.48	12.50	12.49			
EOC	C/40	11.0	25.46	16.82	16.87	16.85	16.85	5	23	13
EOS		12.0		13.22	13.20	13.22	13.21	2	1	1
9. EOD	C/100	20.0	18.52	11.92	11.92	11.93	11.92	-	-	-
SOC	C/50			12.45	12.45	12.47	12.46			
EOC	C/50	13.8	24.53	16.88	16.94	16.92	16.92	8	10	8
EOS		12.0		13.18	13.16	13.18	13.17	2	-	-
10. EOD	C/100	20.0	18.99	11.87	11.88	11.89	11.88	-	-	1
SOC	C/67			12.34	12.34	12.36	12.35			
EOC	C/67	17.4	24.03	16.82	16.87	16.84	16.84	6	7	14
EOS		12.0		13.22	13.21	13.22	13.21	2	1	-
11. EOD	C/100	20.0	18.99	11.86	11.87	11.88	11.87	-	-	-
SOC	C/100			12.25	12.25	12.27	12.25			
EOC	C/100	25.0	23.01	16.72	16.76	16.74	16.74	8	7	10
EOS		12.0		13.27	13.25	13.25	13.26	-	-	-
12. EOD	C/100	20.0	18.98	11.84	11.86	11.87	11.86	2	-	-
SOC	C/200			12.15	12.16	12.17	12.16			
EOC	C/200	47.0	20.70	16.46	16.49	16.47	16.47	7	5	5
EOS		12.0		13.30	13.28	13.29	13.29	-	-	-

*Conditions 1-6 are at the 90 percent level and 7-12 are at the 80 percent level.
**Total Loss during indicated time period

EOD - End of discharge
SOC - Start-of-charge
EOC - End-of-charge
EOS - End-of-stand

STATE-OF-CHARGE EVALUATION TEST DATA AT 50°C
DELCO-REMY 2000
(C = 93 Ampere-Hours)

Condition*	Rate	Time (Hrs)	Ampere Hours	Battery Voltages #1	#2	#3	Avg.	Battery** Water Loss (gm. #1	#2	#3
1. EOD	C/100	10.0	9.54	12.95	12.91	12.93	12.93	-	-	-
SOC	C/33			13.27	13.20	13.24	13.24			
EOC	C/33	6.4	17.81	16.11	16.15	16.13	16.13	15	18	17
EOS		12.0		13.18	13.15	13.16	13.16	3	-	2
2. EOD	C/100	10.0	9.49	12.95	12.91	12.93	12.93	3	5	0
SOC	C/40			12.24	13.20	13.21	13.22			
EOC	C/40	7.0	16.25	16.04	16.08	16.05	16.06	11	7	7
EOS		12.0		13.21	13.17	13.19	13.19	-	4	1
3. EOD	C/100	10.0	9.49	12.95	12.91	12.93	12.93	-	-	-
SOC	C/50			13.20	13.16	13.18	13.18			
EOC	C/50	8.8	16.56	15.96	15.99	15.97	15.97	11	10	10
EOS		12.0		13.23	13.20	13.20	13.22	3	1	4
4. EOD	C/100	10.0	9.46	12.95	12.91	12.93	12.93	-	1	-
SOC	C/67			13.16	13.12	13.14	13.14			
EOC	C/67	11.8	16.25	15.85	15.88	15.86	15.86	13	11	12
EOS		12.0		13.24	13.20	13.22	13.22	-	-	-
5. EOD	C/100	10.0	9.49	12.95	12.91	12.93	12.93	-	1	-
SOC	C/100			13.12	13.08	13.08	13.09			
EOC	C/100	17.5	16.15	15.67	15.71	15.69	15.69	11	14	8
EOS		12.0		13.25	13.20	13.22	13.22	1	1	1
6. EOD	C/100	10.0	9.48	12.95	12.92	12.93	12.93	-	-	-
SOC	C/200			13.07	13.04	13.05	13.05			
EOC	C/200	30.1	13.55	15.25	15.27	15.27	15.26	10	10	9
EOS		12.0		13.24	13.19	13.22	13.22	-	1	-
7. EOD	C/100	20.0	18.98	12.85	12.81	12.83	12.83	1	1	-
SOC	C/33			13.15	13.13	13.14	13.14			
EOC	C/33	9.1	24.46	16.05	16.09	16.07	16.07	11	9	8
EOS		12.0		13.32	13.27	13.29	13.29	2	1	4
8. EOD	C/100	20.0	18.97	12.84	12.80	12.82	12.82	1	2	2
SOC	C/40			13.10	13.06	13.08	13.08			
EOC	C/40	11.0	25.18	15.98	16.00	15.99	15.99	12	12	11
EOS		12.0		13.34	13.29	13.32	13.32	-	-	-
9. EOD	C/100	20.0	18.58	12.84	12.80	12.80	12.81	-	3	-
SOC	C/50			13.07	13.03	13.05	13.05			
EOC	C/50	13.8	25.44	15.88	15.91	15.90	15.90	13	14	9
EOS		12.0		13.35	13.31	13.33	13.33	-	-	-
10. EOD	C/100	20.0	18.97	12.83	12.79	12.81	12.81	1	-	-
SOC	C/67			13.03	12.99	13.01	13.01			
EOC	C/67	18.4	25.19	15.76	15.79	15.78	15.78	10	11	7
EOS		12.0		13.35	13.31	13.33	13.33	1	2	1
11. EOD	C/100	20.0	18.98	12.83	12.79	12.81	12.81	2	1	-
SOC	C/100			12.98	12.95	12.96	12.96			
EOC	C/100	27.5	25.25	15.58	15.62	15.60	15.60	12	11	9
EOS		12.0		13.35	13.31	13.33	13.33	1	1	2
12. EOD	C/100	20.0	18.97	12.82	12.78	12.80	12.80	1	-	2
SOC	C/200			12.93	12.85	12.91	12.90			
EOC	C/200	54.0	24.29	15.17	15.22	15.23	15.21	8	10	4
EOS		12.0		13.26	13.26	13.28	13.26	2	2	1

*Conditions 1-6 are at the 90 percent level and 7-12 are at the 80 percent level.
**Total Loss during indicated time period

EOD - End of discharge
SOC - Start-of-charge
EOC - End-of-charge
EOS - End-of-stand

STATE-OF-CHARGE EVALUATION TEST DATA AT -20°C
J. C. PENNEY SURVIVOR 72
(C = 70 Ampere-Hours)

Condition*		Rate	Battery Time (Hrs)	Battery Ampere Hours	Battery Voltages #1	#2	#3	Avg.	Water Loss (gm) #1	#2	#3
1.	EOD	C/100	10.0	7.22	12.34	12.38	12.38	12.37	-	-	-
	SOC	C/33			12.88	12.95	12.92	12.92			
	EOC	C/33	5.9	20.99	16.78	16.80	17.01	16.86	13	9	[illegible]
	EOS		12.0		13.04	13.09	13.08	13.07	-	-	-
2.	EOD	C/100	10.0	7.00	12.32	12.36	12.36	12.35	-	-	-
	SOC	C/40			12.75	12.80	12.79	12.79			
	EOC	C/40	7.0	11.95	16.73	16.77	16.99	16.83	13	14	22
	EOS		12.0		12.98	13.02	13.03	13.00	-	-	-
3.	EOD	C/100	10.0	7.23	12.31	12.35	12.35	12.34	-	-	[illegible]
	SOC	C/50			12.66	12.70	12.69	12.68			
	EOC	C/50	8.8	12.10	16.60	16.64	16.87	16.70	10	13	5
	EOS		12.0		12.99	13.03	13.05	13.02	-	2	-
4.	EOD	C/100	10.0	7.02	12.29	12.34	12.34	12.32	-	-	-
	SOC	C/67			12.60	12.64	12.64	12.63			
	EOC	C/67	11.7	12.05	16.53	16.56	16.79	16.63	7	10	1[illegible]
	EOS		12.0		13.03	13.06	13.08	13.07	-	-	-
5.	EOD	C/100	10.0	7.16	12.29	12.33	12.33	12.32	-	-	-
	SOC	C/100			12.50	12.59	12.58	12.57			
	EOC	C/100	16.0	10.80	16.38	16.42	16.64	16.48	6	6	5
	EOS		12.0		13.07	13.10	13.12	13.10	-	-	-
6.	EOD	C/100	10.0	7.24	12.28	12.32	12.33	12.31	-	-	-
	SOC	C/200			12.48	12.52	12.52	12.51			
	EOC	C/200	27.8	9.09	16.12	16.15	16.35	16.21	3	3	3
	EOS		12.0		13.15	13.19	13.20	13.18	-	-	-
7.	EOD	C/100	20.0	14.50	12.23	12.27	12.27	12.26	-	-	[illegible]
	SOC	C/33			12.68	12.72	12.71	12.70			
	EOC	C/33	9.1	19.13	16.78	16.80	17.04	16.87	10	11	1[illegible]
	EOS		12.0		13.05	13.08	13.11	13.14	-	-	-
8.	EOD	C/100	20.0	14.50	12.20	12.24	12.24	12.23			
	SOC	C/40			12.60	12.64	12.63	12.63			
	EOC	C/40	11.4	19.66	16.74	16.77	17.01	16.84	10	10	1[illegible]
	EOS		12.0		13.07	13.10	13.14	13.10	1	-	-
9.	EOD	C/100	20.0	14.49	12.18	12.22	12.22	12.21	-	-	-
	SOC	C/50			12.54	12.59	12.58	12.57			
	EOC	C/50	13.0	17.93	16.67	16.70	16.94	16.77	7	6	8
	EOS		12.0		13.09	13.11	13.15	13.12	-	-	-
10.	EOD	C/100	20.0	14.30	12.16	12.20	12.20	12.19			
	SOC	C/67			12.48	12.52	12.52	12.51			
	EOC	C/67	18.4	18.95	16.61	16.64	16.88	16.71	7	8	7
	EOS		12.0		13.13	13.16	13.20	13.23	-	-	-
11.	EOD	C/100	20.0	14.42	12.15	12.19	12.20	12.18	-	-	-
	SOC	C/100			12.43	12.47	12.47	12.45			
	EOC	C/100	26.0	17.62	16.48	16.51	16.74	16.58	8	7	5
	EOS		12.0		13.18	13.21	13.24	13.21	-	1	-
12.	EOD	C/100	20.0	14.42	12.14	12.18	12.19	12.17	-	-	1
	SOC	C/200			12.35	12.39	12.39	12.38			
	EOC	C/200	47.0	16.07	16.19	16.23	16.45	16.29	3	4	4
	EOS		12.0		13.31	13.35	13.33	13.33	-	-	1

* Conditions 1-6 are at the 90 percent level and 7-12 are at the 80 percent level.
** Total Loss during indicated time period

EOD - End-of-discharge
SOC - Start-of-charge
EOC - End-of-charge
EOS - End-of-stand

STATE-OF-CHARGE EVALUATION TEST DATA AT 50°C
J. C. PENNEY SURVIVOR 72
(C = 70 Ampere-Hours)

Condition*	Rate	Time (Hrs)	Ampere Hours	Battery Voltages #1	#2	#3	Avg.	Battery** Water Loss (gm) #1	#2	#3
1. EOD	C/100	10.0	7.25	12.72	12.75	12.73	12.73	2	2	2
SOC	C/33			13.09	13.12	13.07	13.09			
EOC	C/33	5.9	12.33	15.58	15.60	15.98	15.72	9	8	8
EOS		12.0		12.89	12.93	12.92	12.91	-	-	-
2. EOD	C/100	10.0	7.25	12.73	12.76	12.70	12.73	-	1	-
SOC	C/40			13.11	13.14	13.07	13.10			
EOC	C/40	7.0	12.11	15.54	15.56	15.82	15.64	8	11	8
EOS		12.0		12.89	12.92	13.43	13.08	-	-	
3. EOD	C/100	10.0	7.24	12.73	12.76	13.05	12.85	-	2	2
SOC	C/50			13.06	13.09	13.37	13.17			
EOC	C/50	8.8	12.11	15.42	15.44	16.00	15.62	10	16	11
EOS		12.0		12.89	12.93	12.79	12.87	-	1	-
4. EOD	C/100	10.0	7.09	12.73	12.76	12.82	12.77	-	1	-
SOC	C/67			12.99	13.02	13.07	13.03			
EOC	C/67	11.7	12.05	15.32	15.33	15.76	15.48	9	12	8
EOS		12.0		12.90	12.93	13.00	12.94	-	-	-
5. EOD	C/100	10.0	7.23	12.73	12.77	12.81	12.77	-	1	-
SOC	C/100			12.92	12.95	13.00	12.96			
EOC	C/100	17.6	11.94	15.13	15.13	16.24	15.50	8	8	7
EOS		12.0		12.90	12.94	13.24	13.03	-	1	2
6. EOD	C/100	10.0	7.12	12.74	12.77	12.83	12.78	-	2	-
SOC	C/200			12.86	12.89	12.96	12.91			
EOC	C/200	33.1	10.95	14.70	14.69	15.09	14.82	1	2	1
EOS		12.0		12.91	12.96	12.95	12.94	-	-	-
7. EOD	C/100	20.0	14.45	12.68	12.72	12.91	12.77	1	1	1
SOC	C/33			12.97	13.00	13.18	13.05			
EOC	C/33	9.1	19.16	15.73	15.73	16.20	15.89	10	9	7
EOS		12.0		12.96	13.00	13.13	13.03	-	-	-
8. EOD	C/100	20.0	14.50	12.68	12.71	12.78	12.72	-	-	-
SOC	C/40			12.96	12.99	13.04	13.00			
EOC	C/40	11.0	19.01	15.65	15.63	16.19	15.82	7	11	8
EOS		12.0		12.98	13.03	13.08	13.03	-	-	-
9. EOD	C/100	20.0	14.49	12.68	12.71	12.71	12.70	1	3	3
SOC	C/50			12.93	12.96	12.95	12.95			
EOC	C/50	13.8	19.04	15.52	15.49	15.85	15.62	8	11	9
EOS		12.0		13.00	13.05	13.05	13.03	-	-	-
10. EOD	C/100	20.0	14.47	12.68	12.71	12.82	12.74	-	-	-
SOC	C/67			12.89	12.92	13.02	12.94			
EOC	C/67	18.4	19.10	15.37	15.32	16.04	15.58	3	7	4
EOS		12.0		13.01	13.07	13.15	13.08	1	2	1
11. EOD	C/100	20.0	14.48	12.67	12.70	12.68	12.68	2	2	1
SOC	C/100			12.81	12.84	12.81	12.82			
EOC	C/100	28.4	19.41	15.14	15.05	15.63	15.27	5	11	7
EOS		12.0		13.04	13.09	13.21	13.11	-	1	-
12. EOD	C/100	20.0	15.01	12.67	12.70	12.76	12.71	-	3	-
SOC	C/200			12.79	12.81	12.88	12.83			
EOC	C/200	41.0	13.68	13.42	13.43	13.61	13.49	1	6	-
EOS		12.0		13.02	13.04	13.15	13.07	-	-	-

*Conditions 1-6 are at the 90 percent level and 7-12 are at the 80 percent level.
**Total Loss during indicated time period

EOD - End of discharge
SOC - Start-of-charge
EOC - End-of-charge
EOS - End-of-stand

STATE-OF-CHARGE EVALUATION TEST DATA AT -20°C
GLOBE UNION GC 12550
(C = 56 Ampere-Hours)

Condition*	Rate	Time (Hrs)	Ampere Hours	Battery Voltages #1	#2	#3	Avg.	Battery** Water Loss (gm) #1	#2	#.
1. EOD	C/100	10.0	6.0	12.42	12.44	12.42	12.43	-	-	-
SOC	C/33			13.17	13.20	13.17	13.18			
EOC	C/33	7.0	17.50	16.35	16.45	16.38	16.39	14	15	14
EOS		12.0		13.22	13.26	13.22	13.23	1	-	-
2. EOD	C/100	10.0	6.00	12.37	12.39	12.37	12.38	-	-	-
SOC	C/40			12.89	12.91	12.90	12.90			
EOC	C/40	7.0	9.98	16.30	16.39	16.33	16.34	10	10	8
EOS		12.0		13.13	13.17	13.14	13.15	-	-	-
3. EOD	C/100	10.0	6.00	12.35	12.37	12.35	12.36	-	1	-
SOC	C/50			12.72	12.74	12.74	12.74			
EOC	C/50	8.8	10.12	16.19	16.28	16.21	16.23	9	11	13
EOS		12.0		13.14	13.17	13.14	13.15	2	-	-
4. EOD	C/100	10.0	6.01	12.34	12.35	12.34	12.34	-	-	-
SOC	C/67			12.66	12.67	12.67	12.66			
EOC	C/67	11.7	10.00	16.12	16.22	16.15	16.16	6	9	9
EOS		12.0		13.16	13.20	13.16	13.17	-	-	-
5. EOD	C/100	10.0	6.00	12.33	12.35	12.33	12.34	-	-	-
SOC	C/100			12.61	12.62	12.61	12.61			
EOC	C/100	16.0	9.22	15.99	16.09	16.02	16.03	4	4	8
EOS		12.0		13.18	13.22	13.18	13.19	-	-	-
6. EOD	C/100	10.0	6.00	12.34	12.35	12.34	12.34	-	-	-
SOC	C/200			12.55	12.57	12.56	12.56			
EOC	C/200	27.0	7.44	15.73	15.82	15.75	15.77	2	1	3
EOS		12.0		13.20	13.24	13.21	13.22	-	-	-
7. EOD	C/100	20.0	12.00	12.22	12.24	12.23	12.23	-	1	-
SOC	C/33			12.63	12.65	12.65	12.65			
EOC	C/33	9.1	15.91	16.39	16.47	16.43	16.43	7	10	11
EOS		12.0		13.13	13.17	13.14	13.15	-	-	1
8. EOD	C/100	20.0	12.00	12.19	12.21	12.19	12.20	-	-	-
SOC	C/40			12.56	12.57	12.57	12.57			
EOC	C/40	11.4	16.27	16.34	16.43	16.40	16.39	7	8	8
EOS		12.0		13.14	13.17	13.14	13.15	-	-	1
9. EOD	C/100	20.0	12.00	12.16	12.20	12.19	12.19	-	-	-
SOC	C/50			12.51	12.52	12.52	12.52			
EOC	C/50	13.9	16.00	16.30	16.39	16.36	16.35	4	3	5
EOS		12.0		13.14	13.18	13.15	13.16	-	-	-
10. EOD	C/100	20.0	12.00	12.17	12.19	12.18	12.18	-	-	-
SOC	C/67			12.46	12.48	12.47	12.47			
EOC	C/67	18.4	15.67	16.24	16.32	16.28	16.28	5	5	1
EOS		12.0		13.15	13.19	13.16	13.17	-	-	-
11. EOD	C/100	20.0	12.00	12.17	12.19	12.18	12.18	-	-	-
SOC	C/100			12.42	12.44	12.43	12.43			
EOC	C/100	26.0	14.99	16.10	16.19	16.14	16.14	3	3	3
EOS		12.0		13.17	13.21	13.18	13.19	-	-	-
12. EOD	C/100	20.0	12.00	12.17	12.19	12.18	12.18	-	-	-
SOC	C/200			12.38	12.40	12.39	12.39	-	-	1
EOC	C/200	49.0	13.51	15.78	15.90	15.80	15.83	1	-	3
EOS		12.0		13.20	13.25	13.22	13.22	-	-	-

*Conditions 1-6 are at the 90 percent level and 7-12 are at the 80 percent level.
**Total Loss during indicated time period

EOD - End of discharge
SOC - Start-of-charge
EOC - End-of-charge
EOS - End-of-stand

STATE-OF-CHARGE EVALUATION TEST DATA AT 50°C
GLOBE UNION GC 12550
(C = 58 Ampere-Hours)

Condition*	Rate	Time (Hrs)	Ampere Hours	Battery Voltages #1	#2	#3	Avg.	Battery** Water Loss (gm.) #1	#2	#3
1. EOD	C/100	10.0	6.01	12.76	12.79	12.79	12.78	1	2	0
SOC	C/33			13.09	13.10	13.12	13.10			
EOC	C/33	5.8	10.34	15.32	15.41	15.52	15.39	3	2	3
EOS		12.0		13.03	13.05	13.05	13.04	1	1	1
2. EOD	C/100	10.0	6.00	12.77	12.79	12.80	12.79	-	-	-
SOC	C/40			13.06	13.08	13.09	13.07			
EOC	C/40	7.0	10.01	15.23	15.36	15.47	15.35	2	3	2
EOS		12.0		13.03	13.05	13.05	13.04	1	2	-
3. EOD	C/100	10.0	6.00	12.77	12.80	12.80	12.79	1	2	0
SOC	C/50			13.02	13.03	13.05	13.03			
EOC	C/50	8.8	10.12	15.04	15.23	15.35	15.21	4	2	0
EOS		12.0		13.03	13.04	13.05	13.04	-	1	-
4. EOD	C/100	10.0	6.00	12.77	12.80	12.81	12.79	-	1	-
SOC	C/67			12.97	12.99	13.00	12.99			
EOC	C/67	11.7	10.00	14.71	15.06	15.18	14.98	4	2	5
EOS		12.0		13.03	13.05	13.05	13.04	-	-	-
5. EOD	C/100	10.0	6.00	12.77	12.80	12.81	12.79	-	1	-
SOC	C/100			12.92	12.95	12.96	12.94			
EOC	C/100	17.6	10.10	14.33	14.70	14.90	14.64	1	4	1
EOS		12.0		13.02	13.04	13.04	13.03	1	1	1
6. EOD	C/100	10.0	6.00	12.77	12.80	12.81	12.79	1	-	-
SOC	C/200			12.88	12.91	12.92	12.90			
EOC	C/200	23.0	6.61	13.36	13.37	13.40	13.37	1	-	-
EOS		12.0		13.01	13.03	13.04	13.03	-	-	-
7. EOD	C/100	20.0	12.00	12.69	12.72	12.72	12.71	-	-	-
SOC	C/33			12.96	12.98	12.99	12.98			
EOC	C/33	9.1	16.03	15.22	15.45	15.53	15.40	3	3	0
EOS		12.0		13.04	13.06	13.06	13.05	1	-	1
8. EOD	C/100	20.0	12.00	12.68	12.71	12.71	12.70	-	1	-
SOC	C/40			12.90	12.93	12.93	12.92	3	4	4
EOC	C/40	11.0	15.68	14.92	15.26	15.27	15.15			
EOS		12.0		13.05	13.07	13.07	13.06	-	-	-
9. EOD	C/100	20.0	11.97	12.68	12.71	12.71	12.70	-	1	-
SOC	C/50			12.87	12.90	12.90	12.88			
EOC	C/50	13.8	15.87	14.72	15.10	15.24	15.02	2	3	-
EOS		12.0		13.05	13.07	13.07	13.06	-	-	-
10. EOD	C/100	20.0	12.00	12.68	12.71	12.71	12.70	1	2	-
SOC	C/67			12.83	12.87	12.87	12.85			
EOC	C/67	18.4	15.64	14.46	14.85	15.04	14.78	2	-	1
EOS		12.0		13.04	13.06	13.07	13.06	-	-	-
11. EOD	C/100	20.0	11.92	12.67	12.71	12.71	12.70	-	-	-
SOC	C/100			12.80	12.84	12.84	12.82			
EOC	C/100	28.4	16.21	13.79	13.96	13.99	13.92	-	2	-
EOS		12.0		13.03	13.06	13.06	13.05	-	-	-
12. EOD	C/100	20.0	11.89	12.66	12.71	12.71	12.69	-	-	-
SOC	C/200			12.76	12.80	12.80	12.79			
EOC	C/200	41.0	11.62	13.27	13.31	13.31	13.30	3	2	0
EOS		12.0		12.97	13.01	13.01	13.00	-	-	-

*Conditions 1-6 are at the 90 percent level and 7-12 are at the 80 percent level.
**Total Loss during indicated time period

EOD - End of discharge
SOC - Start-of-charge
EOC - End-of-charge
EOS - End-of-stand

STATE-OF-CHARGE EVALUATION TEST DATA AT -20°C
NIFE - NICKEL-CADMIUM - L-302-2
(C = 55 Ampere-Hours)

Condition*	Rate	Time (Hrs)	Ampere Hours	Battery Voltages #1	#2	#3	Avg.	Battery** Water Loss (gm) #1	#2	#3
1. EOD	C/100	10.0	5.77	13.37	13.34	13.37	13.34	-	-	-
SOC	C/33			13.85	13.82	13.86	13.84			
EOC	C/33	5.8	9.61	17.64	17.59	17.60	17.61	5	5	6
EOS		12.0		14.29	14.19	14.22	14.23	-	1	-
2. EOD	C/100	10.0	5.75	13.34	13.31	13.34	13.33	-	-	1
SOC	C/40			13.79	13.75	13.80	13.78			
EOC	C/40	7.0	9.51	17.55	17.50	17.51	17.52	7	7	8
EOS		12.0		14.32	14.21	14.25	14.26	-	-	1
3. EOD	C/100	10.0	5.75	13.33	13.30	13.34	13.32	-	1	-
SOC	C/50			13.75	13.71	13.75	13.74			
EOC	C/50	8.8	9.68	17.45	17.41	17.41	17.42	6	3	4
EOS		12.0		14.35	14.24	14.27	14.29	4	4	2
4. EOD	C/100	10.0	5.75	13.33	13.31	13.34	13.33	1	2	-
SOC	C/67			13.69	13.66	13.70	13.69			
EOC	C/67	11.8	9.49	17.30	17.27	17.27	17.28	4	5	6
EOS		12.0		14.38	14.27	14.29	14.32	4	2	3
5. EOD	C/100	10.0	5.74	13.34	13.30	13.34	13.32	2	2	-
SOC	C/100			13.63	13.59	13.64	13.62			
EOC	C/100	16.1	8.87	17.12	17.09	17.09	17.10	7	5	5
EOS		12.0		14.38	14.26	14.28	14.31	-	1	2
6. EOD	C/100	10.0	5.75	13.32	13.29	13.22	13.28	1	-	-
SOC	C/200			13.53	13.50	13.36	13.52			
EOC	C/200	28.0	7.39	16.78	16.76	16.76	16.77	3	2	-
EOS		12.0		14.46	14.31	14.36	14.38	1	2	2
7. EOD	C/100	20.0	11.50	13.07	13.04	13.07	13.06	1	2	1
SOC	C/33			13.55	13.51	13.56	13.54			
EOC	C/33	9.0	15.00	17.72	17.67	17.66	17.68	8	4	6
EOS		12.0		14.37	14.24	14.25	14.29	1	2	1
8. EOD	C/100	20.0	11.41	13.05	13.02	13.05	13.04	-	-	-
SOC	C/40			13.50	13.47	13.51	13.49			
EOC	C/40	11.0	14.94	17.63	17.58	17.57	17.59	9	8	10
EOS		12.0		14.48	14.36	14.34	14.40	-	1	-
9. EOD	C/100	20.0	11.49	12.71	12.69	12.72	12.71	-	2	-
SOC	C/50			13.12	13.09	13.13	13.11			
EOC	C/50	13.8	14.62	17.33	17.30	17.28	17.31	3	3	-
EOS		12.0		14.62	14.48	14.49	14.53	-	-	-
10. EOD	C/100	20.0	11.48	12.83	12.80	12.84	12.82	-	-	-
SOC	C/67			13.20	13.18	13.22	13.20			
EOC	C/67	18.4	15.03	17.32	17.28	17.27	17.29	4	3	-
EOS		12.0		14.57	14.42	14.42	14.47	4	-	-
11. EOD	C/100	20.0	11.46	12.91	12.89	12.92	12.91	2	-	-
SOC	C/100			13.23	13.20	13.25	13.22			
EOC	C/100	26.0	14.07	17.16	17.13	17.12	17.14	3	3	3
EOS		12.0		14.55	14.43	14.40	14.46	1	1	-
12. EOD	C/100	20.0	11.48	12.93	12.90	12.94	12.92	-	-	-
SOC	C/200			13.16	13.13	13.16	13.15			
EOC	C/200	47.0	12.18	16.81	16.81	16.78	16.80	6	3	3
EOS		12.0		14.53	14.42	14.39	14.44	2	1	-

*Conditions 1-6 are at the 90 percent level and 7-12 are at the 80 percent level.
**Total Loss during indicated time period

EOD - End of discharge
SOC - Start-of-charge
EOC - End-of-charge
EOS - End-of-stand

MDEC/C 83-75

STATE-OF-CHARGE EVALUATION TEST DATA AT 50°C
NIFE - NICKEL-CADMIUM - L-302-2
(C = 55 Ampere-Hours)

Condition*	Rate	Time (Hrs)	Ampere Hours	Battery Voltages #1	#2	#3	Avg.	Battery** Water Loss (gm) #1	#2	#3
1. EOD	C/100	10.0	5.50	12.79	12.76	12.79	12.78	1	2	
SOC	C/33			13.00	13.00	13.00	13.00			
EOC	C/33	6.4	10.52	15.07	15.04	15.08	15.06	9	9	8
EOS		12.0		13.53	13.51	13.54	13.52	3	3	3
2. EOD	C/100	10.0	5.50	12.77	12.74	12.77	12.76	-	-	2
SOC	C/40			12.95	12.92	12.96	12.94			
EOC	C/40	7.0	9.54	14.96	14.93	14.98	14.96	9	9	8
EOS		12.0		13.51	13.49	13.52	13.52	2	5	3
3. EOD	C/100	10.0	5.50	12.75	12.72	12.76	12.74	1	-	1
SOC	C/50			12.92	12.89	12.93	12.91			
EOC	C/50	9.0	9.84	14.86	14.84	14.89	14.86	7	4	1
EOS		12.0		13.48	13.48	13.52	13.49	3	5	3
4. EOD	C/100	10.0	5.37	12.74	12.70	12.74	12.73	-	1	2
SOC	C/67			12.89	12.86	12.90	12.88			
EOC	C/67	11.7	9.48	14.72	14.72	14.77	14.73	7	10	6
EOS		12.0		13.46	13.45	13.50	13.47	-	3	1
5. EOD	C/100	10.0	5.74	12.72	12.69	12.73	12.71	-	3	-
SOC	C/100			12.86	12.83	12.87	12.86			
EOC	C/100	17.5	9.60	14.55	14.55	14.58	14.56	8	8	12
EOS		12.0		13.43	13.41	13.47	13.44	-	4	1
6. EOD	C/100	10.0	5.80	12.71	12.68	12.72	12.90	-	4	-
SOC	C/200			12.83	12.80	12.84	12.82			
EOC	C/200	29.0	7.50	14.30	14.28	14.33	14.31	5	4	-
EOS		12.0		13.29	13.29	13.38	13.32	-	5	3
7. EOD	C/100	20.0	11.48	12.67	12.64	12.68	12.66	-	5	-
SOC	C/33			12.88	12.84	12.89	12.87			
EOC	C/33	9.1	15.00	15.02	14.99	15.04	15.02	5	5	6
EOS		12.0		13.49	13.47	13.55	13.50	1	3	3
8. EOD	C/100	20.0	11.47	12.66	12.63	12.67	12.65	N/A	4	-
SOC	C/40			12.85	12.82	12.86	12.84			
EOC	C/40	9.0	14.77	14.98	14.95	15.00	14.98	N/A	9	11
EOS		12.0		13.53	13.46	13.54	13.51	N/A	2	3
9. EOD	C/100	20.0	11.29	12.65	12.62	12.66	12.64	N/A	4	1
SOC	C/50			12.82	12.79	12.83	12.82			
EOC	C/50	13.8	15.12	14.91	14.87	14.92	14.90	N/A	13	11
EOS		12.0		13.52	13.45	13.53	13.50	N/A	3	3
10. EOD	C/100	20.0	11.47	12.64	12.61	12.65	12.63	N/A	2	2
SOC	C/67			12.80	12.77	12.81	12.79			
EOC	C/67	18.4	11.75	14.80	14.75	14.81	14.78	N/A	12	7
EOS		12.0		13.48	13.42	13.50	13.47	N/A	3	1
11. EOD	C/100	20.0	11.47	12.63	12.60	12.63	12.62	N/A	4	1
SOC	C/100			12.78	12.74	12.78	12.77			
EOC	C/100	26.0	14.21	14.60	14.44	14.61	14.55	N/A	13	11
EOS		12.0		13.41	13.37	13.45	13.41	N/A	3	3
12. EOD	C/100	20.0	11.49	12.61	12.57	12.62	12.60	N/A	4	-
SOC	C/200			12.74	12.71	12.75	12.73			
EOC	C/200	50.0	13.69	14.37	14.23	14.39	14.33	N/A	15	11
EOS		12.0		13.23	13.25	13.30	13.26	N/A	7	2

*Conditions 1-6 are at the 90 percent level and 7-12 are at the 80 percent level.
**Total Loss during indicated time period

EOD - End of discharge
SOC - Start-of-charge
EOC - End-of-charge
EOS - End-of-stand
N/A - Not Applicable

APPENDIX F

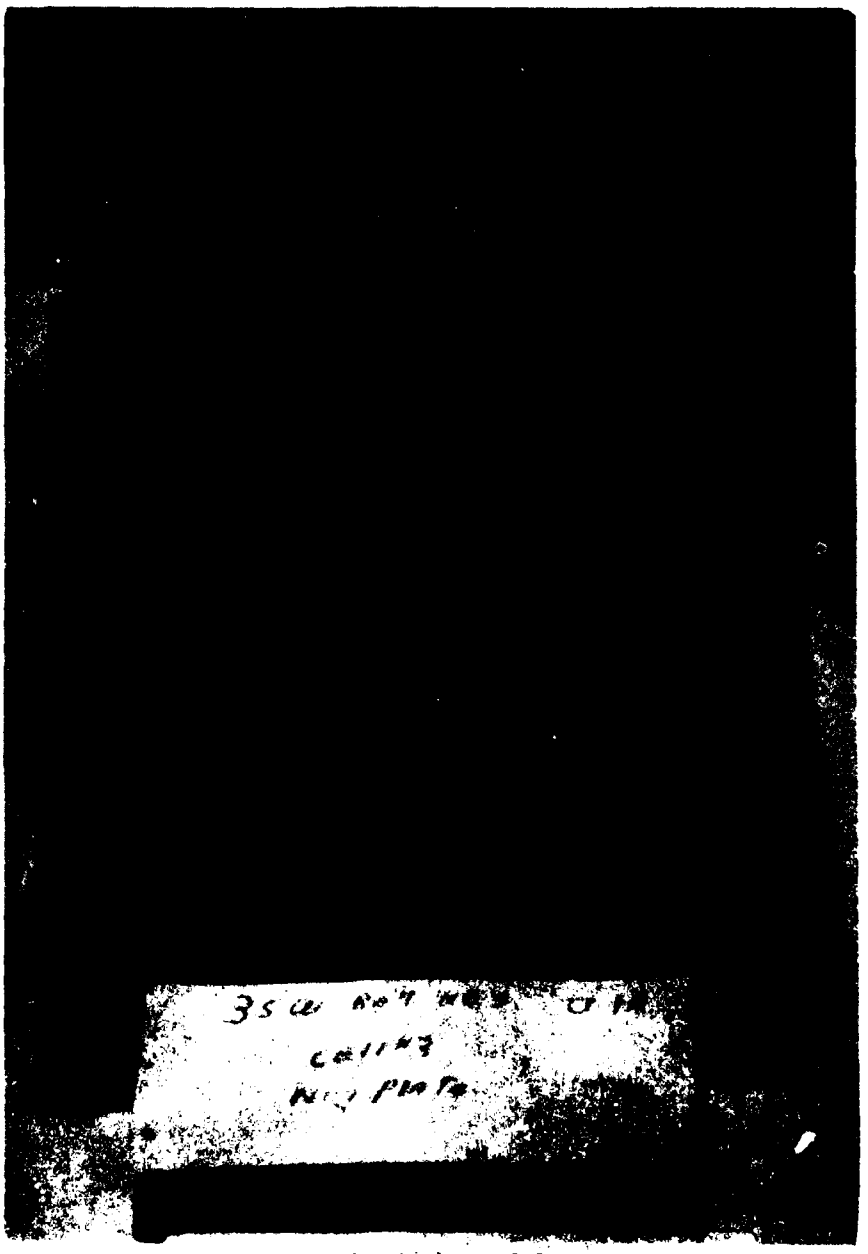
FAILURE ANALYSIS RESULTS

FAILURE ANALYSIS RESULTS
WILLARD (Cycled) DD-3-3

Pack Number 35W

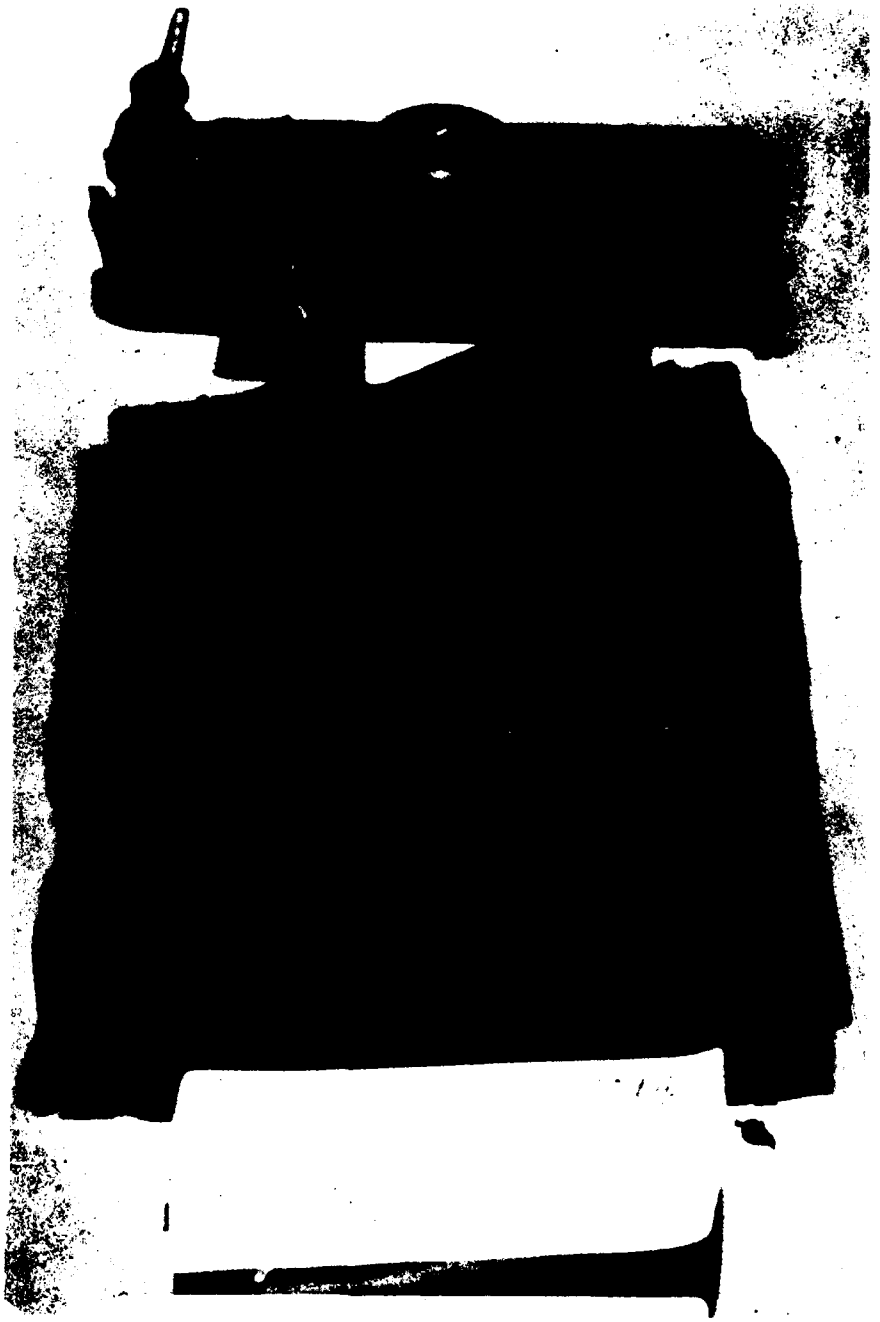
	U1A Batt# 1 Cell 3	U1B Batt#2 Cell 1	U2A Batt# 3 Cell 3	U2B Cell 1
1. POSITIVE PLATES				
a. Grid corroded, structure weak				
b. Hard and brittle				
c. Sulfated				
d. Shedding of active material	X	X	X	X
e. Buckled				
f. Plate to post (mechanical integrity)				
g. Post to intercell connector (mechanical integrity)				
2. NEGATIVE PLATES				
a. Swelled				
b. Hard and sandy				
c. Sulfated	X	X	slight	slight
d. Loss of active material				
e. Buckled				
f. Plate to post (mechanical integrity)				
g. Post to intercell connector (mechanical integrity)				
3. SEPARATOR				
a. Moist				
b. Dry				
c. Adhered to positive plate				
d. Discolored (blackened)				
e. Hot spots			*	*
f. Alignment - poor				
4. CASE				
a. Positive terminal corroded	X	X	X	X
b. Negative terminal corroded			slight	slight
c. Cracked sealant	X	X	X	X
d. Bulged				
e. Sediment in bottom - slight				
f. Sediment in bottom - moderate	X	X	X	X
g. Sediment in bottom - soft short				

*-located under fill port



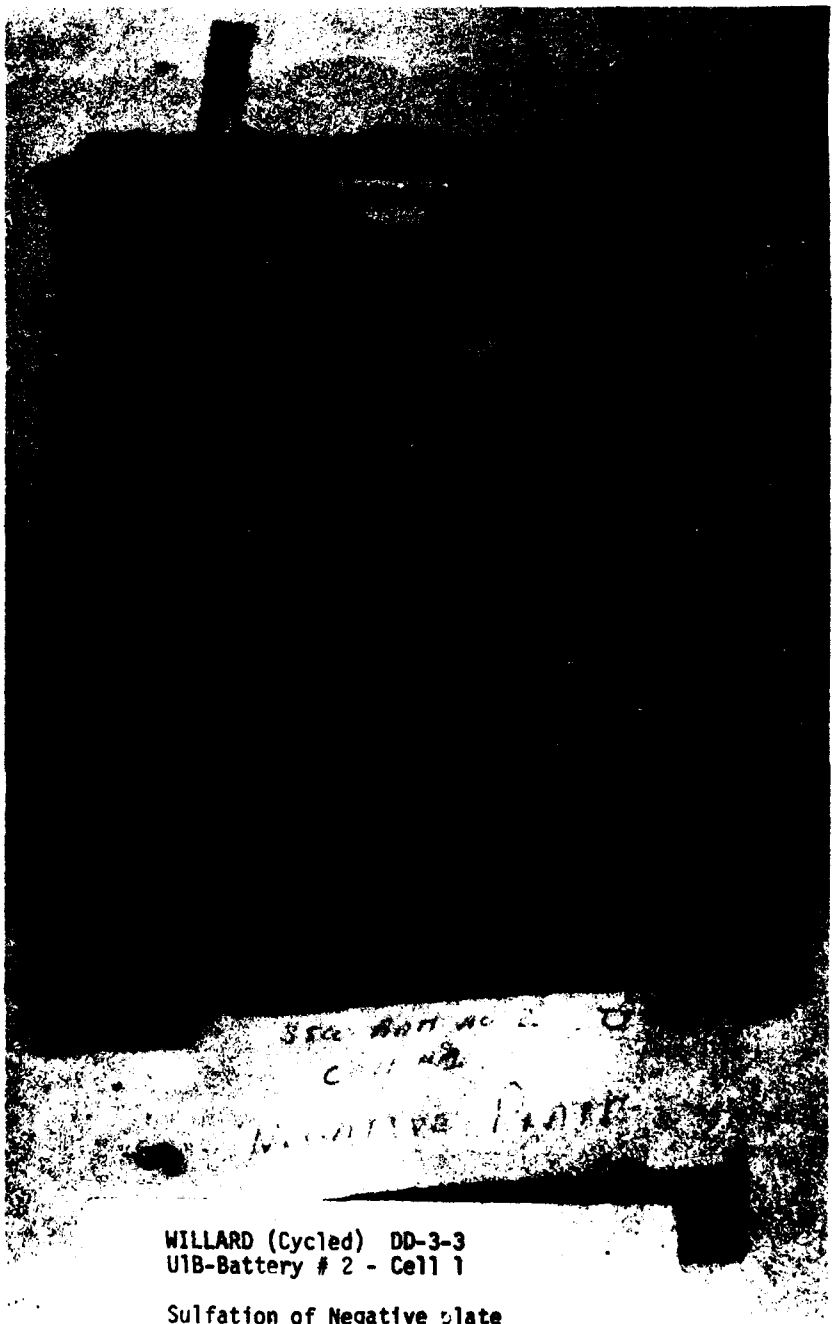
WILLARD (Cycled) DD-3-3
U1ABattery # 1 - Cell 3

Sulfation of Negative plate
Photograph # 1



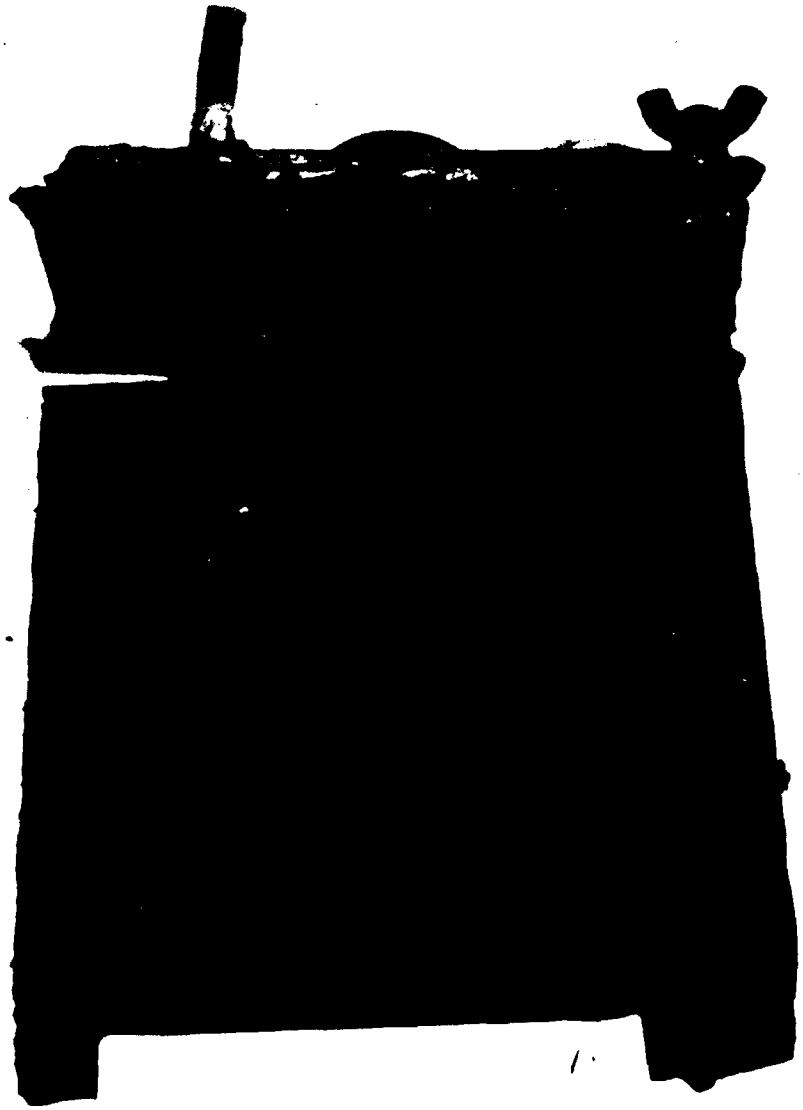
WILLARD (Cycled) DD-3-3
U1A-Battery # 1 - Cell 3

Shedding of positive material, glass mat adhered to positive plate
Photograph # 2



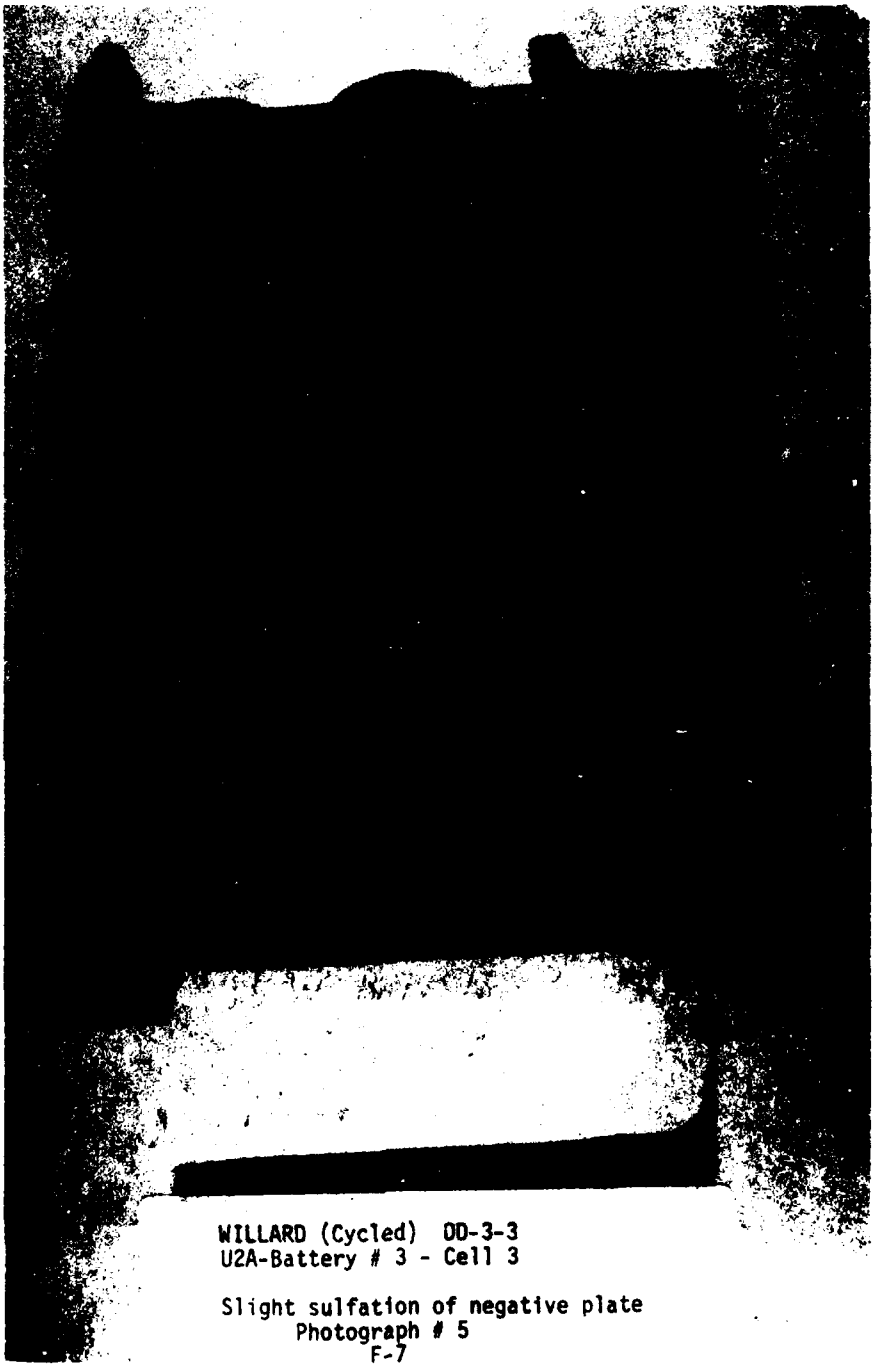
WILLARD (Cycled) DD-3-3
U1B-Battery # 2 - Cell 1

Sulfation of Negative plate
Photograph # 3
F-5



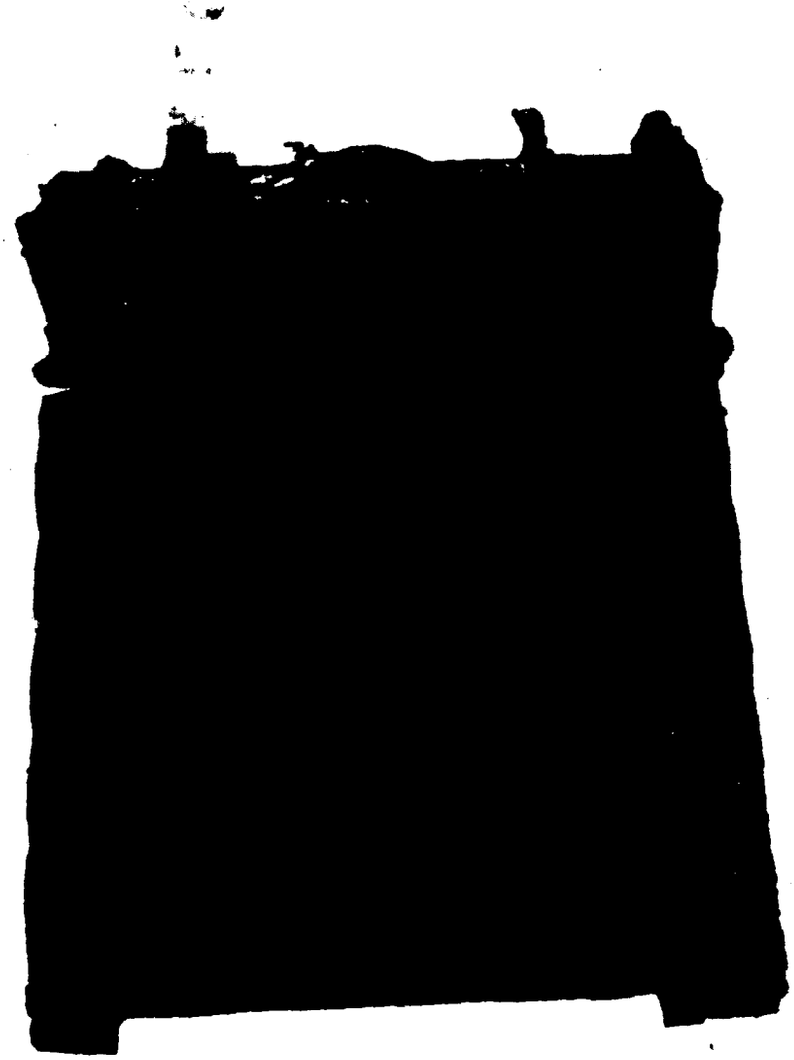
WILLARD (Cycled) DD-3-3
U1B-Battery # 2 - Cell 1

Shedding of positive material
Photograph # 4
F-6



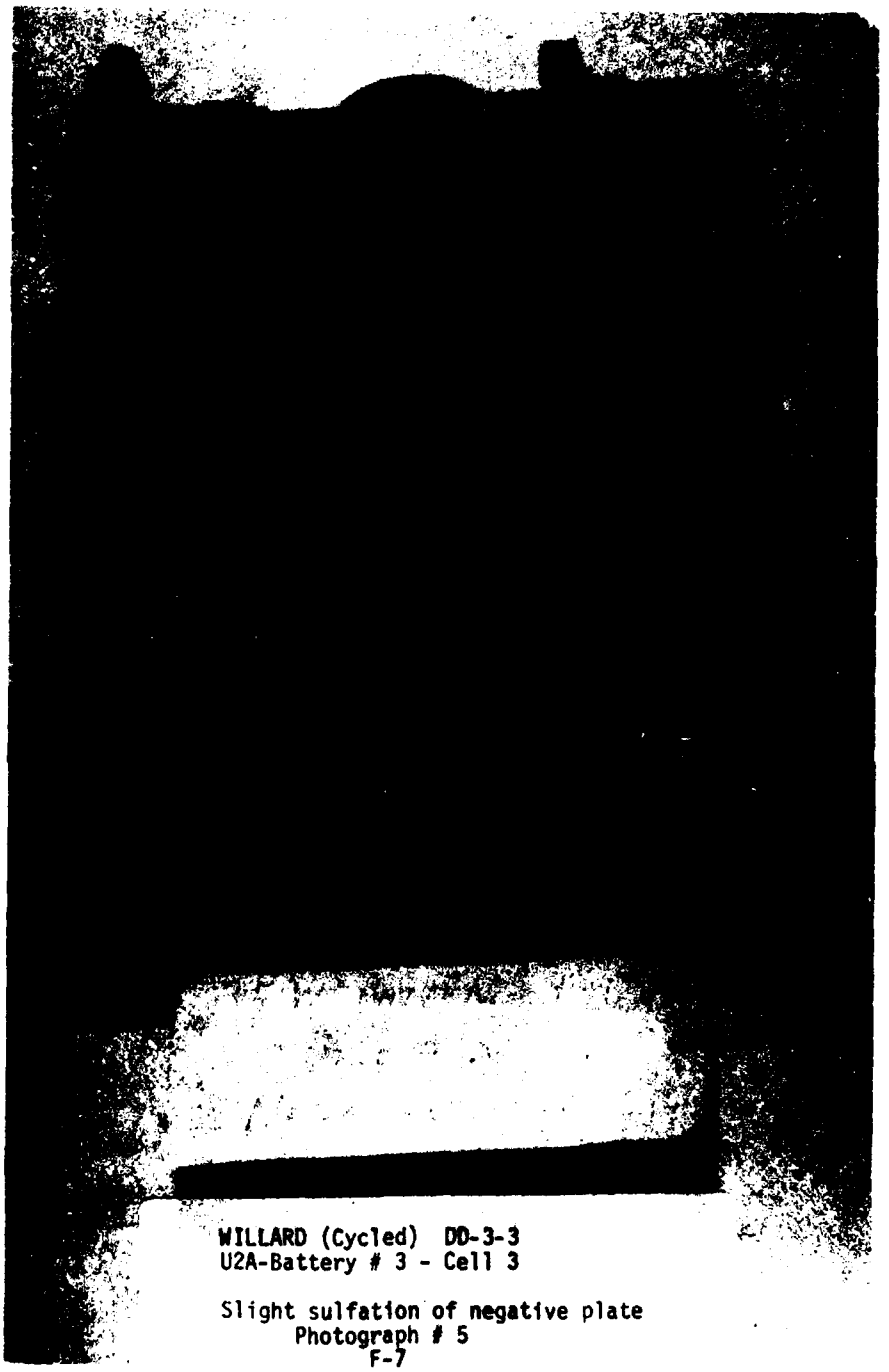
WILLARD (Cycled) OD-3-3
U2A-Battery # 3 - Cell 3

Slight sulfation of negative plate
Photograph # 5



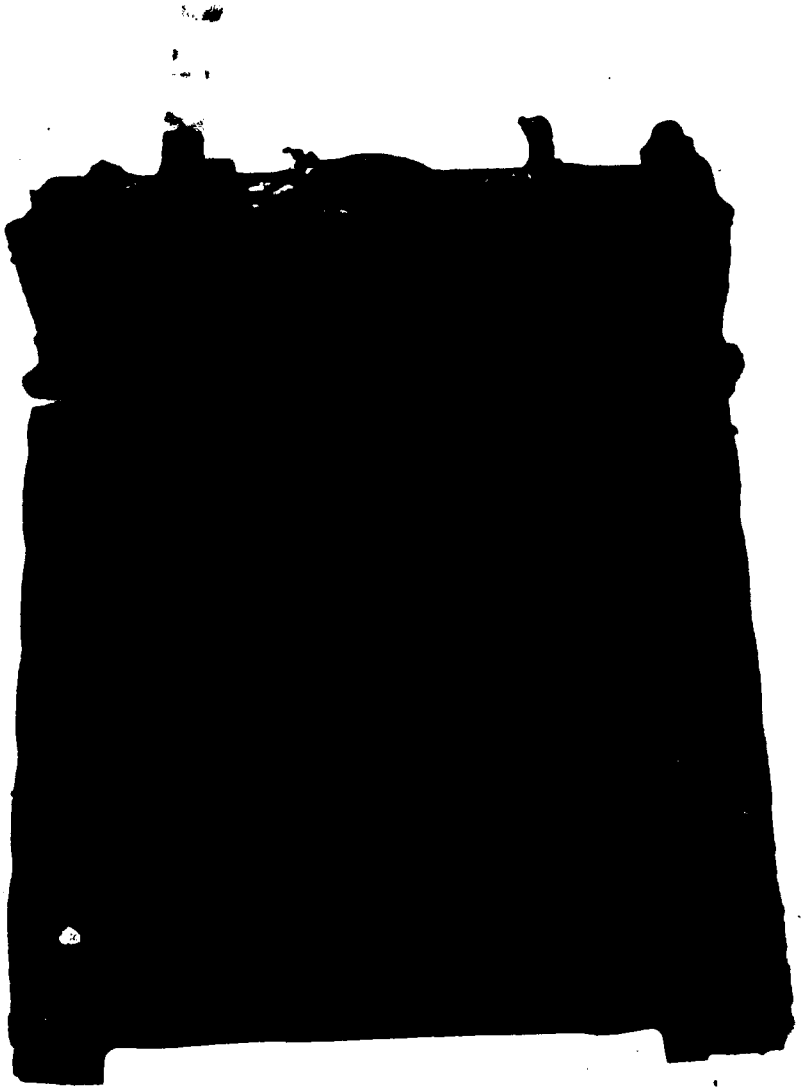
WILLARD (Cycled DD-3-3
U2A-Battery # 3 - Cell 3

Shedding of positive material
Photograph # 6
F-8



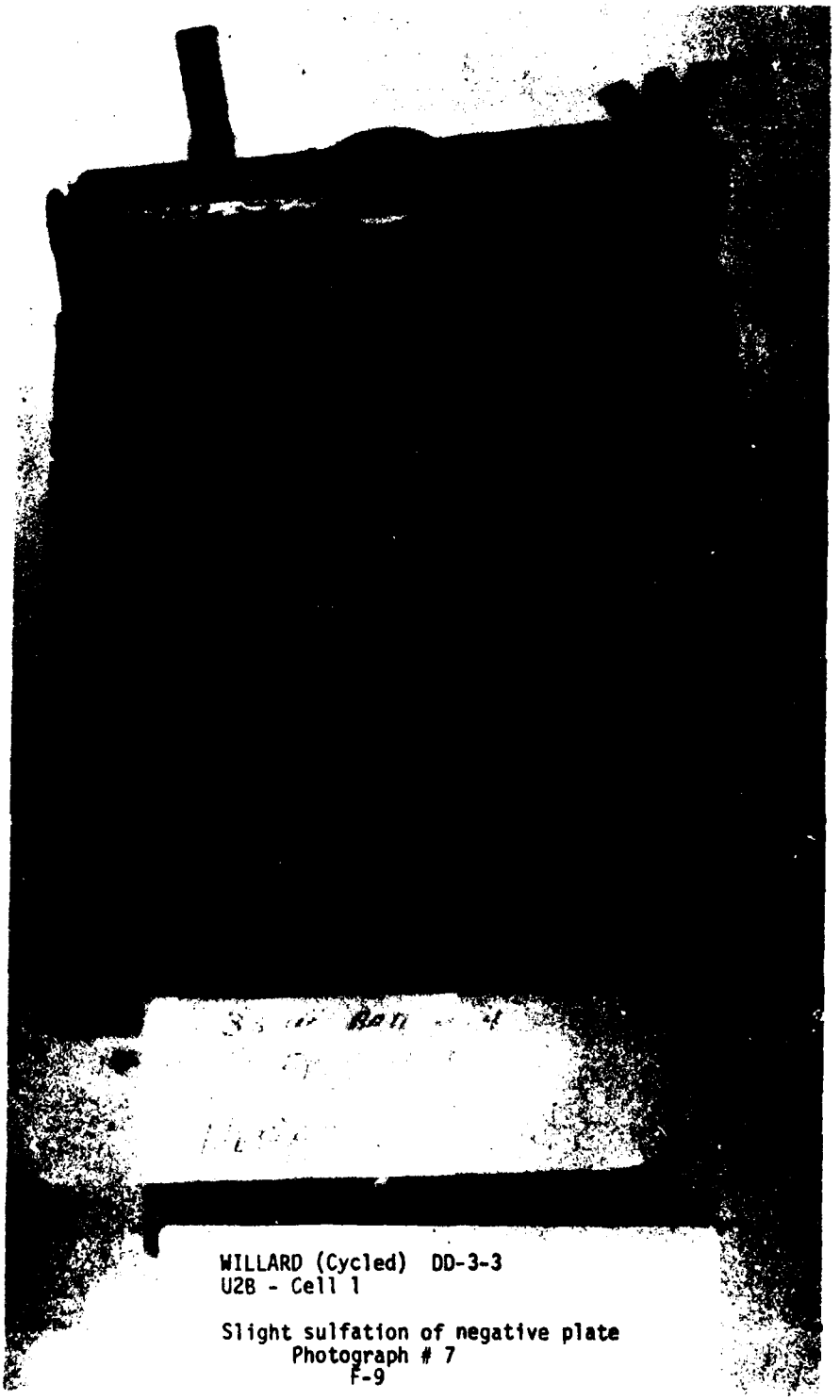
WILLARD (Cycled) DD-3-3
U2A-Battery # 3 - Cell 3

Slight sulfation of negative plate
Photograph # 5
F-7



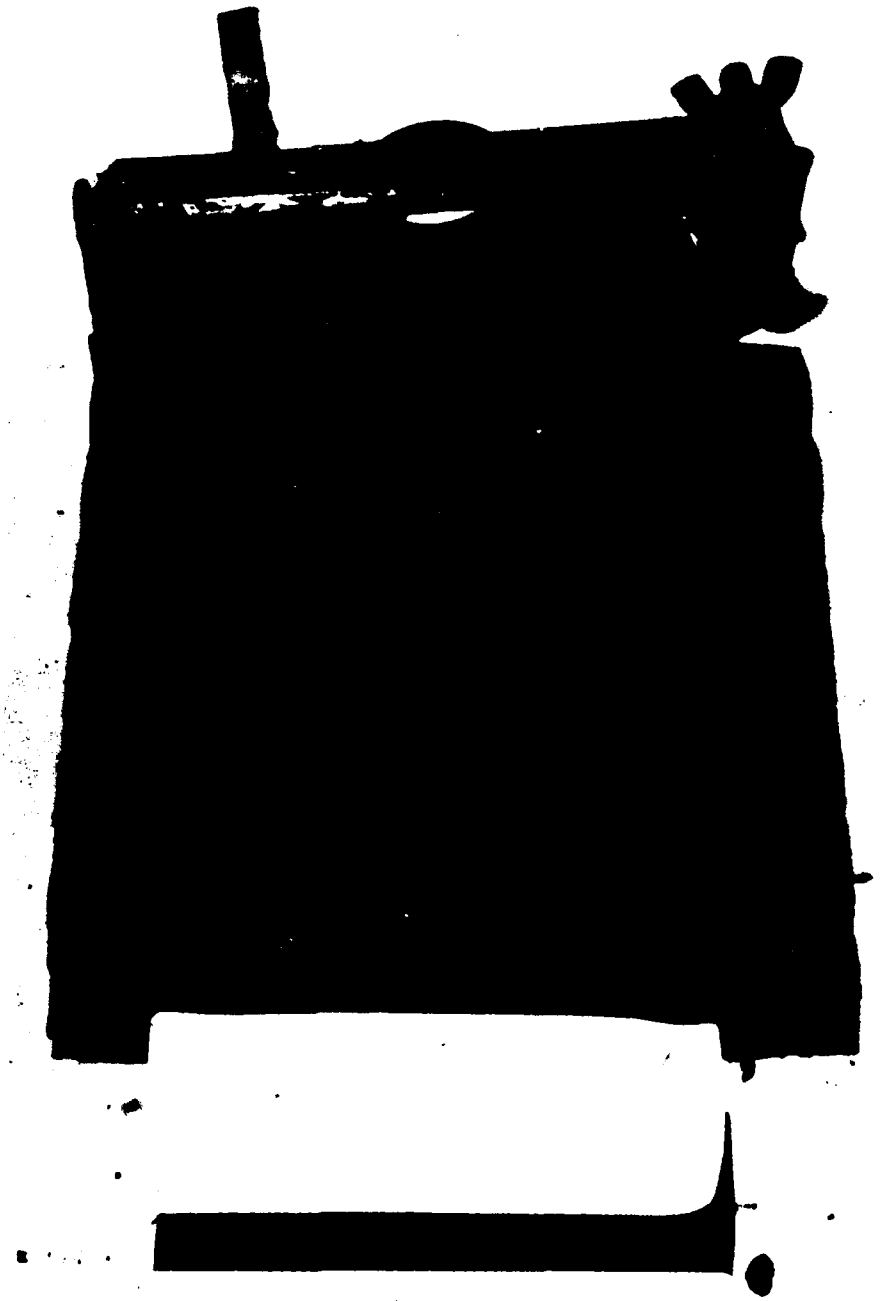
WILLARD (Cycled DD-3-3
U2A-Battery # 3 - Cell 3

Shedding of positive material
Photograph # 6
F-8



WILLARD (Cycled) DD-3-3
U2B - Cell 1

Slight sulfation of negative plate
Photograph # 7
F-9



WILLARD (Cycled) DD-3-3
U2B - Cell 1

Shedding of positive material
Photograph # 8
F-10

APPENDIX G

TEST FACILITIES

TEST FACILITIES

A. ENVIRONMENTAL CHAMBERS

The ambient test temperatures or -20°C and 50°C were maintained by environmental chambers with temperature controls accurate to within ±1.5°C.

B. AUTOMATIC DATA ACQUISITION AND CONTROL SYSTEM (ADACS)

1. Summary:

a. The system has the capability of testing 256 packs with 3000 channels available for data input from these packs.

(1) Each battery type was placed into a pack configuration, with the 3 batteries in series, in which each pack had its own power supply with its corresponding system interface, remotely programmed by the system to provide its test requirements. During test, the system routinely scans each pack's data every 2.4 minutes and compares each data point (voltage, temperature) with programmed limits to insure that the test items meet test specifications. If the parameter is out of limits the system will initiate and alarm and also type out a message identifying which pack's parameter was out of limits.

(2) As data is being scanned, it is recorded on magnetic tape and also on a teletype, in report form, if requested.

(3) The system was designed to provide an accuracy of 1.0 millivolt on directly read data and cell voltages. The accuracy of temperature (thermistor) measurements are 0.05°C.

b. The system is organized into three functional hardware groupings as follows.

(1) Computer and computer peripherals:

(a) Honeywell 316 computer and options;

(b) Two ASR15 heavy duty teletypes;

(c) Honeywell 316-50 high speed paper tape reader and spooler;

(d) Datum, Inc., Model 5091-H316 magnetic tape I/O system with two tape transports;

(e) Datum, Inc., Model 6078-H316 mass memory system with 131,000 word drum memory;

(f) Tally, Model 2200 line printers;

(g) Texas Instruments Silent 700 Deck Printer.

(2) Auxiliary digital functions include:

(a) Real-time clock, system shut-down timer and alarm circuits, and medium-speed analog input subsystem;

(b) Two John Fluke, Model 8300-A digitizers;

(c) 3000-channel reed relay scanner.

(2) Control subsystem:

(a) 256 control channels providing the digital-to-resistance conversion and control-relay outputs to the interface between the system and the test items.

2. Measurements:

a. Currents are measured by sampling the voltage drop across a low-resistance shunt of 100 MV full current value. Through output measurement, error of the shunt voltage is 1 millivolt maximum.

b. Cell and ambient temperatures are measured by sampling the output of a thermistor bridge driven by an excitation voltage. The temperature range is -30°C to +70°C and is resolved in increments of 0.1°C, with an error or less than 0, 05°C, resulting from linearity.

c. Battery voltages, which exceed 10 volts, are attenuated by resistors to the extent that the scanner system measures a maximum of 10 volts.

3. Calibration:

a. The system was designed for a maximum throughput measurement error of 1.0 millivolt.

b. The digitizers are routinely calibrated off-line; and, when on-line, are compared with a secondary standard reference voltage each scan to insure maximum system accuracy.

C. INTERFACE CONTROLS

The control units for charge and discharge of ten cells are controlled by the relays on the Digital to Resistance (D/R) cards of the ADACS. The D/R cards can control the voltage and current on a power supply up to 1/256 of current or voltage required.

D. WEIGHT MEASUREMENTS

1. Water-loss was measured utilizing a Toledo Scale Weighting System which consisted of:

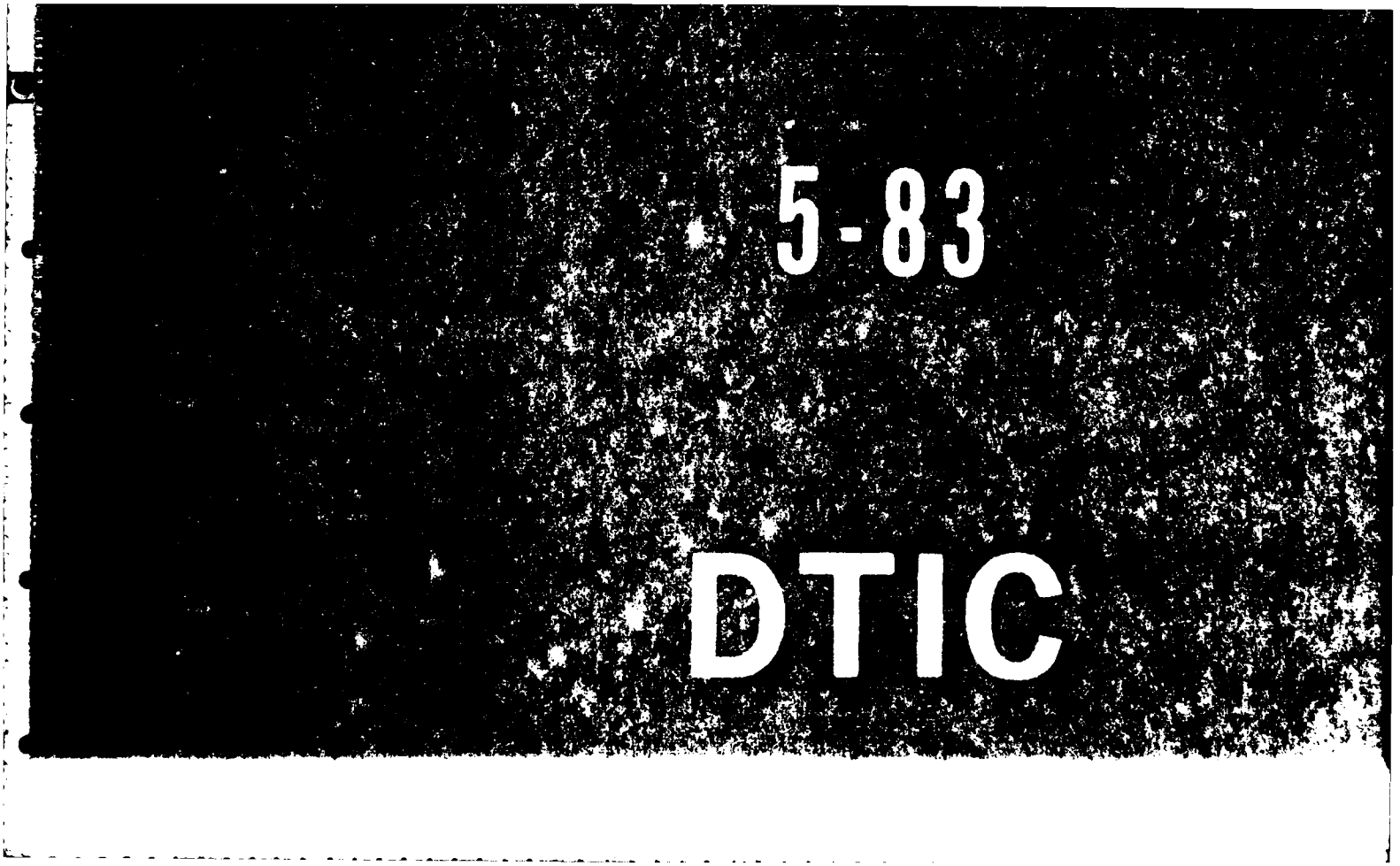
a. Six, 1985 Base and Platform Assemblies

b. Model 132 Scale Selector

c. Model 8130 Digital Indicator

d. Model 131 Tare Assembly

2. System was designed and calibrated for an accuracy of $\pm$ 1.0 gram.


5-83
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